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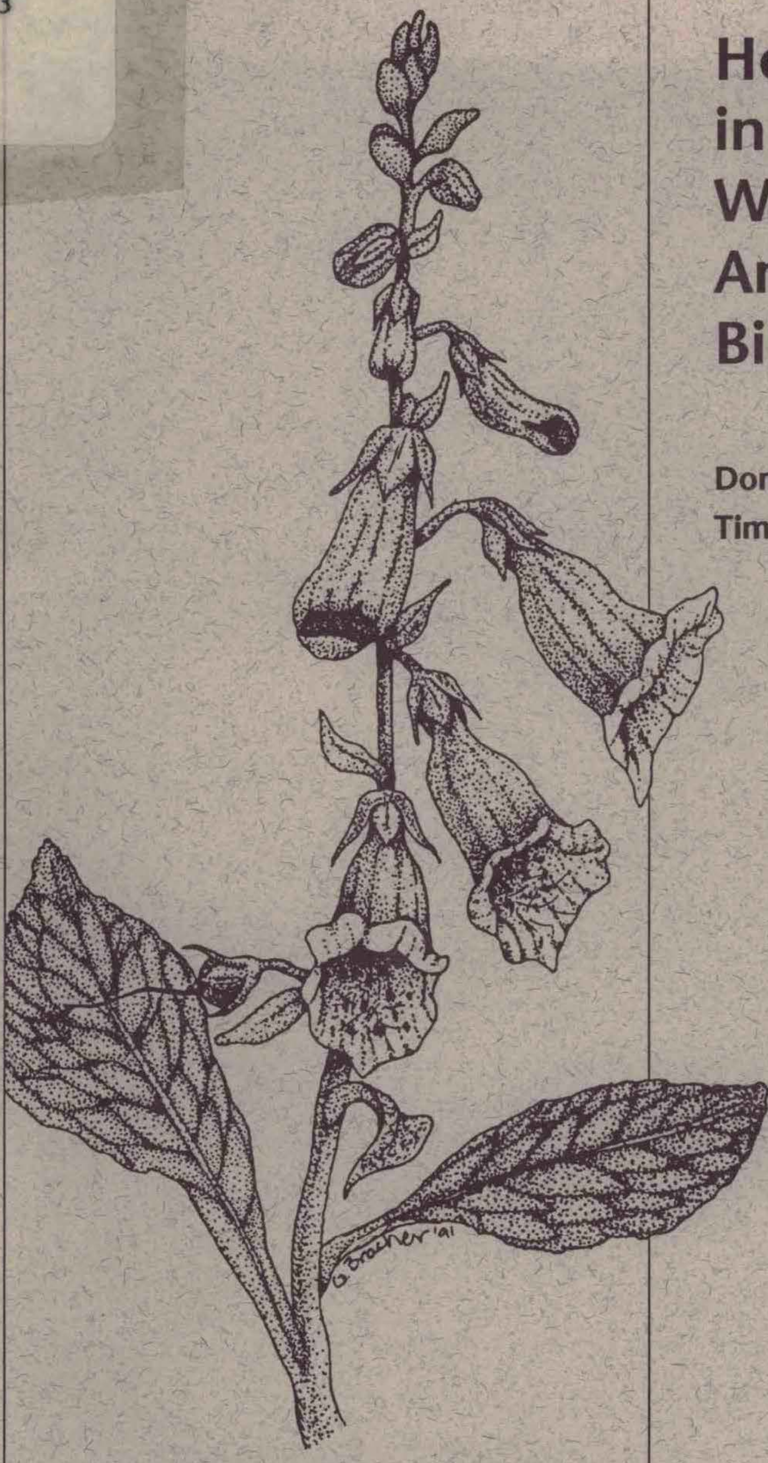
Herbaceous Vegetation in Forests of the Western United States: An Annotated Bibliography

Donna M. Loucks
Timothy B. Harrington



Foxglove (*Digitalis purpurea*)

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Contents

Introduction

Herbaceous (nonwoody) plant species are dominant members of forest communities recovering from disturbance such as fire or timber harvest. They can compete with shrubs and trees for soil water, nutrients, and sometimes light, thus delaying successional development in forest stands. Herbaceous plants in forested areas provide forage for wildlife and livestock. Often grasses and legumes are seeded to disturbed areas to reduce soil erosion and promote vegetal development.

This bibliography is a compilation of research information on herbaceous vegetation in forests of the western United States. Topics covered include effects on stand development and soil processes and systems for managing herbaceous species to increase production of timber and animal forage. In our review of the literature, we focused on forestry research from the western U.S. since 1970; however, we have included some abstracts that predate this period. Citations and abstracts of 325 articles are included. Most of the information presented is related to management of herbaceous species and their effects on development of conifer species. The literature predominantly pertained to ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) in the Rocky Mountains and Pacific Northwest.

This publication was supported by CRAFTS (Coordinated Research on Alternative Forestry Treatments and Systems), a research cooperative in forest vegetation management at Oregon State University.

Effects of Herbaceous Vegetation on Development of Young Forest Stands

1. **BARON, F.J. 1962. Effects of different grasses on ponderosa pine seedling establishment. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note 199. 8 p.**

   Ponderosa pine (*Pinus ponderosa*) and eight species of grass (*Poa ampla, Festuca ovina* var. *duriuscula, Agropyron trichophorum, Agrostis alba, Dactylis glomerata, Lolium perenne, Arrhenatherum elatius,* and *Phleum pratense*) were planted together on a burned area. Less than half the pines were dead after 3 years, whether or not they were in grassy areas. When pine was planted in 1-year-old grass, 80% died, whereas only 30% of those planted in the absence of grass died. Grass species differed in their effect on tree survival.

2. **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.**

   This study was concerned with the patterns of vegetative changes that occur during the first 5 years after logging and burning on Douglas-fir clearcuts. The vegetation in the study area was a Douglas-fir/vine maple (*Pseudotsuga menziesii/Acer circinatum*) association. Salal (*Gaultheria shallon*) and Cascade Oregon grape (*Berberis nervosa*) dominated the forest floor, with traces of chinkapin (*Castanopsis* spp.), hazelnut (*Corylus* spp.), and dogwood (*Cornus* spp.). Study plots were located on nine clearcut and burned areas ranging in elevation from 1,300 to 2,800 feet and including north, south, and east exposures. Nineteen study plots (100 by 100 feet) were established in uniformly vegetated areas. Plots were also established in undisturbed areas adjacent to the clearcuts for comparative purposes. Vegetative sampling was done with an ocular point frame in both spring and fall of the second, third, fourth and fifth years following burning. The stable undisturbed vegetation was sampled only once.

   Total number of plant species generally increased during the 5-year study. The average total vegetation cover rose abruptly the third, fourth, and fifth years. An analysis indicated that plots with southern exposure had the greatest vegetative cover the first 5 years after burning. East-facing plots ranked second and north-facing plots third. By the fourth year, average cover values on clearcut areas exceeded the cover values of understory vegetation on the adjacent uncut forest.

Data on seasonal variation showed sharp decreases in total cover from spring to fall during the first 3 years. Increasing amounts of perennial vegetation during the fourth and fifth years reduced this seasonal variation markedly. In terms of mean cover trends, the annual herb wood groundsel (*Senecio sylvaticus*) dominated in the second year, deervetch (*Lotus stipularis*) and bull thistle (*Cirsium vulgare*) in the third, and deervetch and velvetgrass (*Holcus lanatus*) in the fourth and fifth.

3. **BROWN, J.K., and N.V. DeBYLE. 1989. Effects of prescribed fire on biomass and plant succession in western aspen. USDA Forest Service, Intermountain Research Station, Ogden, Utah. Research Paper INT-412. 16 p.**

Plant succession and production of biomass were determined for three prescribed fires in aspen (*Populus tremuloides*) and aspen/conifer forests. Forbs and shrubs dominated the understories. Preburn fuel loadings ranged from 19,200 to 56,400 kg/ha. Fires ranged from low to high severity, and overstory mortality, from 20 to 100%. Over 4 postburn years, production of grasses and forbs averaged 1.5 to 3.3 times that of the controls. Maximum production was 2,240 kg/ha, 5 times that of the associated control. Very severe fire favored forbs over grasses. After 5 years, shrub biomass was 21 to 100% of preburn biomass. Aspen sucker densities peaked during the first 2 postburn years and ranged from 0.5 to 5 times their preburn densities. Suckering was most prolific following fire of moderate to high severity. The varied patterns of seral vegetation and their management implications are discussed.

4. **CAZA, C.L., and J.P. KIMMINS. 1988. The impact of non-coniferous vegetation on the performance of Engelmann spruce (*Picea engelmannii* Parry) seedlings on subalpine forest cutovers in southern B.C. P. 38-40 *in* Vegetation Competition and Responses: Proceedings of the Third Annual Vegetation Management Workshop, Vancouver, British Columbia. E. Hamilton and S. Watts, eds. Canadian Forestry Service and British Columbia Ministry of Forests and Lands, Victoria, British Columbia. FRDA Report 026.**

Vegetation on many cutovers in the Engelmann spruce/subalpine fir zone is dominated by one or both of two major species complexes: an ericaceous shrub complex characterized by false azalea (*Menziesia ferruginea*) and white-flowered rhododendron (*Rhododendron albiflorum*), and a perennial herb complex dominated by Sitka valerian (*Valeriana sitchensis*). The specific objectives of this study were developed from the general hypothesis that herb and shrub complexes differ significantly as competitive environments for seedling growth. These differences may have important implications for the selection of stock types, planting times and locations, and site preparation to improve regeneration success. The study objectives were (1) to describe and compare the edaphic, microclimatic and community characteristics of the herb and shrub complexes on cutovers and in the mature spruce-fir forest; (2) to compare the survival and growth of Engelmann spruce seedlings with and without the presence of above-ground vegetation, and within and between the herb and shrub complexes; (3) to compare the growth and survival of naturally established seedlings and different stock types of Engelmann spruce within and between the herb and shrub complexes; and (4) to determine whether species of the herb complex replace those of the shrub complex in response to removal of above-ground or above- and below-ground vegetation. First-season results are reported briefly.

5. **CHOLEWA, A.F., and F.D. JOHNSON. 1983. Secondary succession in the *Pseudotsuga menziesii*/ *Physocarpus malvaceus* association. Northwest Science 57:273-282.**

Shrub and herbaceous cover were measured on 27 sites within the Douglas-fir zone in northern Idaho. The sites either had not been disturbed since 1900 (climax communities) or had been logged, burned, grazed, logged and burned, or logged and grazed. The successional sequence could not be divided into recognizable discrete stages, but reflected the complexity of secondary succession. Succession from early seral to climax communities may be continuous, and community composition may not be correlated with time since disturbance.

6. CLARK, M.B., and A. McLEAN. 1975. **Growth of lodgepole pine seedlings in competition with different densities of grass. British Columbia Forest Service, Victoria, British Columbia. Research Note 70. 10 p.**

Lodgepole pine (*Pinus contorta*) was grown alone and in competition with orchardgrass (*Dactylis glomerata*) under controlled growth-room conditions for 6 months. Survival, height and plant mass of lodgepole pine decreased significantly as grass density increased. The response of lodgepole pine to grass competition was independent of moisture regime. Growth of orchardgrass was reduced by intraspecific competition.

A second study confirmed the retarding of lodgepole pine development when in competition with grass. This study also indicated a greater effect of lodgepole pine from the nonrhizomatous orchardgrass than from the moderately rhizomatous pinegrass (*Calamagrostis rubescens*). Competition from seeded orchardgrass could slow the growth rate of lodgepole pine.

7. CLARK, M.B., and A. McLEAN. 1979. **Growth of lodgepole pine seedlings in competition with grass. British Columbia Ministry of Forests, Victoria, British Columbia. Research Note 86. 13 p.**

Between 1973 and 1978, lodgepole pine (*Pinus contorta*) was grown from seed under normal forest site conditions. Seedlings were grown alone and in competition with different densities of orchardgrass (*Dactylis glomerata*), with different species of grass (*Dactylis glomerata, Bromus inermis, Phleum pratense, Festuca rubra, Festuca ovina* var. *duriuscula*, and *Agropyron cristatum*), with grass subjected to simulated grazing, and with grass fertilized with nitrogen and sulfur at variable rates.

Survival of lodgepole pine was not affected by density of grass sowing or species of grass, but early height growth of pine and total seedling weight were significantly reduced by high rates of grass sowing.

Addition of fertilizers had no significant effect on grass productivity after the first year following application. Clover (*Trifolium*) on unfertilized areas produced herbage yields equivalent to herbage yields of all grasses on areas with the highest rates of fertilizer application.

8. CLAUSNITZER, R.R. 1979. **Annual understory production as a function of overstory structure and successional status in the *Abies grandis/Pachistima myrsinites* habitat type in the Blue Mountains of southeastern Washington and northeastern Oregon. M.S. thesis, Washington State University, Pullman, Washington. 58 p.**

Understory production and overstory relationships were investigated during the summer of 1977 in the Blue Mountains of Washington and Oregon. The objectives of the study were (1) to determine the relationships between overstory structure and annual production of grasses, forbs, and shrubs in undisturbed stands of the grand fir/myrtle boxwood (*Abies grandis/Pachistima myrsinites*) habitat type; and (2) to determine the relationships between annual understory production and the successional status of undisturbed stands in this habitat type.

These relationships may provide a practical means for prediction of browse and herbage production for livestock and big game. They also provide a framework within which the impact of overstory canopy disturbance on understory productivity may be assessed.

Multiple linear regression techniques were used to construct independent prediction equations for total annual understory production (g/m^2) and current year's production (g/m^2) of 11 understory components: (1) total production, (2) total shrubs, (3) highly preferred shrubs, (4) moderately preferred shrubs, (5) least preferred shrubs, (6) total herbage, (7) total graminoids, (8) grasses, (9) *Carex* and *Luzula*, (10) perennial forbs, and (11) allowable forage crop.

Prediction variables included the following attributes of the tree overstory and forest floor and variables linked to the successional status of stands: (1) canopy coverage, (2) stem density, (3) basal area, (4) sum of diameters, (5) average age of dominant and codominant trees, (6) percentage grand fir of total basal area, (7) diameter of grand fir of average basal area, and (8) litter depth.

The understory production models accounted for 28.5 to 60.7% of the variation in annual production during the period of maximum growth.

9. COATES, K.D. 1987. **Effects of shrubs and herbs on conifer regeneration and microclimate in the *Rhododendron-Vaccinium-Menziesia* community of south-central British Columbia. M.S. thesis, Oregon State University, Corvallis, Oregon. 93 p.**

The impact of interfering vegetation on survival and growth of Engelmann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta* var. *contorta*) was studied at a high-elevation site in south-central British Columbia. The study examined (1) the influence of varying amounts of shrubs and herbs on microclimate and performance of planted seedlings, (2) relationships between various measures of vegetation interference and conifer seedling growth, and (3) the response of six major shrub and herb species to manual cutting and mechanical scarification.

After two growing seasons, survival of both conifers was greater than 97%, except at the highest levels of interfering vegetation, where survival was 82 to 84%. Diameter was the measure of conifer growth most responsive to levels of interference. Height growth generally did not respond to interference levels. Soil water potential was never lower than – 0.01 MPa and was the same at all levels of interference throughout the growing season. Midday and predawn spruce xylem water potential also did not vary by vegetation-removal treatment.

The relationship between growth of individual spruce and pine and various measures of vegetation interference was always negative. Measures of percent vegetation cover were consistently the best predictors of seedling growth. A maximum of 25% of the variation in seedling growth was explained by measures of interference. The response of conifer seedlings to interference may be nonlinear, with a decreasing response observed at high amounts of interference. Large variance in seedling growth at low levels of interference suggests that either microsite variability or genotype differences constrain seedling performance, even in the absence of interference.

The two major herb species, Sitka valerian (*Valeriana sitchensis*) and Indian hellebore (*Veratrum viride*), had recovered to precut levels by early in the second growing season. Vigor of Sitka valerian decreased after multiple cutting. Herb species responded to mechanical scarification as they did to manual cutting.

10. COATES, K.D. 1988. **Effects of shrubs and herbs on conifer regeneration and microclimate in the *Rhododendron-Vaccinium-Menziesia* community of south-central British Columbia. P. 41-42 *In* Vegetation Competition and Responses: Proceedings of the Third Annual Vegetation Management Workshop, Vancouver, British Columbia. E. Hamilton and S. Watts, eds. Canadian Forestry Service and British Columbia Ministry of Forests and Lands, Victoria, British Columbia. FRDA Report 026.**

The impact of interfering vegetation on survival and growth of Engelmann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta* var. *contorta*) was studied at a site in the Engelmann spruce/subalpine fir zone of south-central British Columbia. The study examined (1) the influence of varying amounts of shrubs and herbs on microclimate and planted seedling performance, (2) relationships between various measures of vegetation interference and conifer seedling growth, and (3) the response of six major shrub and herb species to manual cutting and mechanical scarification. The two major herb species, Sitka valerian (*Valeriana sitchensis*) and Indian hellebore (*Veratrum viride*), had recovered to precut levels (both manual and mechanical) by early in the second growing season.

11. **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.**

This thesis examines the competitive aspects of Douglas-fir (*Pseudotsuga menziesii*) trees growing with two common competitors — red alder (*Alnus rubra*) and grass — at varying densities. Two Nelder plots in three different environments in the Oregon Coast Range were studied. Plots ranged in spacing from 300 to 15,250 cm^2/tree and consisted of six "pie-shaped" treatments. The plots had been planted in the spring of 1978 with 2-0 bareroot Douglas-fir nursery stock. Two sections were interplanted with red alder, and two sections were broadcast-seeded with grass the following year.

Douglas-fir growth was inhibited by red alder and grass competition, as well as by competition from other Douglas-fir. Grass competition was severe only during the initial years of the plantation, while red alder competition became more pronounced with time. Growth was a function of density, competitor type, and site; significant interactions occurred among the three factors. Leaf area per tree of Douglas-fir under competition could be predicted by leaf weight, stand density, and competitor type. The formation of shade needles in response to density and competitor type increased the leaf area:leaf weight ratio. Growth efficiency (stemwood volume production/unit of leaf area) was not highest for the most vigorous trees. On a per-hectare basis, high productivity was correlated with high leaf-area index, but the relation was reversed on a per-tree basis.

12. **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.**

Foliar and soil nutrients, canopy light penetration, and predawn moisture stress were measured during 1982 in Douglas-fir (*Pseudotsuga menziesii*). Nelder plots (a series of concentric circles in a "wagon wheel" configuration) were established in 1978 at three sites in the Oregon Coast Range. Douglas-fir spacings ranged from 300 to 15,250 cm^2/tree, alone or in competition with grass or red alder (*Alnus rubra*).

Concentration of foliar nitrogen in Douglas-fir and total and available soil nitrogen did not differ significantly between competition treatments, but differences between sites were significant. Foliar phosphorus was significantly higher in Douglas-fir grown with grass. Both foliar nitrogen and phosphorus were reduced at high densities. Predawn moisture stress varied with site, competitor and density—the lowest stresses occurring for Douglas-fir growing at low densities without competition. Canopy light penetration varied with competitor, density, and height above ground; the lowest values occurred under red alder canopy. It was concluded that grass competed primarily for moisture and that red alder reduced available light and moisture. Nodulated red alder did not increase nitrogen in soil or Douglas-fir foliage on any site or at any density.

13. **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.**

Measurements were made in autumn 1982 in 5-year-old plantations of Douglas-fir (*Pseudotsuga menziesii*) on three site types in the Oregon Coast Range. Trees were planted 17 to 123 cm apart, alone or with grass or red alder (*Alnus rubra*). Crowding and competition from both grass and alder reduced above-ground dry weight per tree. Dry weight/ha was higher at higher tree densities, but this relation is expected to change with time, as the larger trees at low densities form fully stocked stands. Grass affected growth most at the driest site. Although red alder decreased growth on all sites, the effect was most significant at the coastal site, where light is most limiting and moisture least limiting. For the production of maximum individual tree size, low stocking with control of competing vegetation is recommended.

14. **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.**

An experiment was conducted to determine how Douglas-fir (*Pseudotsuga menziesii*) exploits site resources when growing in mixture with grasses or red alder (*Alnus rubra*) or with no competition apart from other Douglas-fir. Douglas-fir 2-0 seedlings were planted in a Nelder design. Treatments included (1) total weed control through the 5 years of the experiment; (2) complete weed control the first year, followed by grass seeding; and (3) planting alternate radii with Douglas-fir and red alder seedlings, with complete weed control for the duration of the experiment.

Average height and diameter of Douglas-fir after 5 years were strongly affected by density of Douglas-fir itself, and less strikingly by grass or alder. Effects of grass alone ranged from negligible to a 10.4-mm decrease in diameter at 15 cm above ground. Both grass and alder decreased height growth by 0 to 0.63 m during the 5-year period. Effect of grass after a year of total weed control was much less than would be anticipated for established grass, but growth impact was still measurable even in environments where moisture is generally not regarded as critical for established trees.

15. **COMEAU, P. 1988. Light attenuation by thimbleberry-fireweed communities in the ICH zone and its potential effects on conifer growth. P. 5-7 *In* Vegetation Competition and Responses: Proceedings of the Third Annual Vegetation Management Workshop, Vancouver, British Columbia. E. Hamilton and S. Watts, eds. Forestry Canada and British Columbia Ministry of Forests and Lands, Victoria, British Columbia. FRDA Report 026.**

In cool, moist areas of the southern interior of British Columbia, dense canopies of noncrop vegetation may develop after harvest and compete with conifer seedlings for light. Thimbleberry (*Rubus parviflorus*) and fireweed (*Epilobium angustifolium*) occur as dominant species in early seral communities on many sites in the Interior Cedar Hemlock (ICH) zone of southern British Columbia. On moist (hygric) rich sites, thimbleberry may develop dense cover, dominating early seral communities. Dense patches of fireweed may occur on some mesic and subhygric sites following fire. This summary presents preliminary results from a study of competition for light in thimbleberry/fireweed communities in the ICHa subzone near Nelson, British Columbia.

16. **COMEAU, P.G., S.B. WATTS, C.L. CAZA, J. KARAKATSOULIS, S.M. THOMSON, and A.B. McGEE. 1989. Autecology, biology, competitive status and response to treatment of seven southern interior weed species. British Columbia Ministry of Forests and Forestry Canada, Victoria, British Columbia. FRDA Report 093. 46 p.**

This report contains a literature review of the autecology and competitive status of seven species that compete with conifer seedlings in the southern interior of British Columbia. Two herbaceous species, pinegrass (*Calamagrostis rubescens*) and fireweed (*Epilobium angustifolium*), are included. This review updates Haeussler and Coates (1986; see abstract 34 for full citation). When no new information could be found, the Haeussler and Coates text was included without change. The review attempts to include all pertinent English language publications published up to and including 1987.

17. **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.**

Allometric equations for 3-year-old Douglas-fir (*Pseudotsuga menziesii*) and red alder (*Alnus rubra*) were developed as part of a replacement-series experiment at Belfair, Washington. The primary objective of the study was to generate equations for predicting seedling component biomass. A second objective was to test the significance of density and proportion in biomass prediction.

Douglas-fir and red alder biomass components were best predicted by stem diameter, total height, and crown width. Density was a significant variable for predicting Douglas-fir leaf biomass and total biomass. However, density was positively correlated with biomass, contrary to normal yield-density relationships, and so was excluded from the model. The percent cover of shrub and herbaceous species was a significant variable for predicting Douglas-fir root biomass. Red alder total biomass was correlated with red alder proportion, indicating that biomass was higher for sample trees growing in stands dominated by red alder than in stands dominated by Douglas-fir.

Generally, the most significant spatial variable for predicting Douglas-fir biomass was the percent cover of shrub and herbaceous species. The most significant spatial variable for predicting red alder biomass was the distance to the nearest neighboring tree. Suggestions are given for determining the roles of density and proportion in allometric equations for use in replacement series experiments.

18. **CRANE, M.F., J.R. HABECK, and W.C. FISCHER. 1983. Early postfire revegetation in a western Montana Douglas-fir forest. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah. Research Paper INT-319. 32 p.**

A severe wildfire destroyed a 1,200-acre forest of second-growth Douglas-fir (*Pseudotsuga menziesii*) near Missoula, Montana, in July 1977. Most of the burned area was aerially seeded with exotic grasses during November 1977, while covered with snow. Pinegrass (*Calamagrostis rubescens*) regrew abundantly from rhizomes after the fire.

Seeded orchardgrass (*Dactylis glomerata*) and the native pinegrass were the most competitive species after 5 years. Orchardgrass was dominant in most areas. Shrubs achieved dominance in most ravines and on some upland sites. On many upland sites, however, secondary colonization by shrubs will be necessary for a well-defined shrub stage to become established. The recovery of understory plants was much more rapid in the ravines than on any upland sites. Tree regeneration was scarce, suggesting that reforestation will be slow.

19. **DIXON, H.N. 1969. The growth of lodgepole pine in the Colorado Front Range as related to environment. Ph.D. dissertation, University of Colorado, Boulder, Colorado. 120 p.**

Growth of lodgepole pine (*Pinus contorta*) in two stands at 10,000 feet elevation was studied in relation to environment for 3 years. The stands, which formed after fires that followed logging, were similar in tree size, density, and canopy cover, but differed in age and soil moisture. Radial changes, cambial activity, mean annual increment, terminal growth, cambial and stem temperature, soil temperature and moisture, and wood moisture were measured or estimated. Differences in growth rate, herbaceous vegetation, and speed of succession to the subalpine spruce/fir climax were related to the differences in soil moisture. The stand on wetter soil had more herbaceous vegetation and was approaching the subalpine spruce-fir climax more rapidly.

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

Cattle grazing, beginning 1 year after planting, enhanced water relations and growth of conifer seedlings on a young plantation in southwest Oregon. Because of the rocky nature of soils on the study area, availability of soil moisture to seedlings was assessed during 1984 with a pressure chamber. Predawn xylem potentials of Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) seedlings were evaluated within three levels of competing vegetation: ungrazed, grazed, and no competition.

In ponderosa pine, little difference in predawn xylem potentials during 1984 was detected among the three levels of competition. Douglas-fir seedlings on the ungrazed plots exhibited significantly more negative predawn xylem potentials earlier in the growing season than did those on the grazed and no-competition treatments. Comparison of both ponderosa pine and Douglas-fir in 1986 between grazed and ungrazed treatments revealed significantly less negative predawn potentials and significantly greater stomatal conductance on grazed plots early in the growing season. Improved water relations was one factor thought to increase growth and vigor of conifer seedlings on the grazed area. After 3 years, seedling volume of both ponderosa pine and Douglas-fir was significantly greater on the grazed plots. Controlled cattle grazing improved plant water relations and enhanced the growth performance of young conifer seedlings.

21. DREW, S.E. 1968. **Soil moisture depletion trends under five plant species present on the Douglas-fir clear-cuts of Marys Peak, Oregon. M.S. thesis, Oregon State University, Corvallis, Oregon. 77 p.**

Trends in depletion of soil moisture under five plant species growing on several clearcuts of the Marys Peak watershed near Corvallis, Oregon, were followed during the summers of 1963 and 1964. These species—velvetgrass (*Holcus lanatus*), big deervetch (*Lotus crassifolius* var. *subglaber*), salal (*Gaultheria shallon*), Cascade Oregon-grape (*Berberis nervosa*), and vine maple (*Acer circinatum*)—were the dominant plants of several stages in a successional sere occurring on the clearcuts. Sampling of the moisture trends was limited to two clearcut areas in order to reduce variability resulting from location. Salal, Oregon-grape, and deervetch were growing in individual, pure stands on one area. On the other, vine maple was growing in closely grouped clumps and velvetgrass occupied the areas in between.

Each species had characteristic trends in moisture depletion during the 2 years. Trends for salal indicated slow moisture loss at all three depths (6, 12, and 24 inches). Depletion trends associated with Oregon-grape were similar to those in salal, except that moisture losses at the 6-inch depth were more rapid under Oregon-grape. Under deervetch, moisture trends at 6 and 12 inches fluctuated considerably. Depletion was rapid at all three depths. Velvetgrass trends showed early and rapid moisture loss at 6 and 12 inches, but a slightly delayed and slower loss at 24 inches. Moisture losses under vine maple were rapid at all three depths and very consistent, with no fluctuations.

This study partially explains how velvetgrass is replaced by deervetch. Deervetch apparently invades velvetgrass by producing rhizomes that grow underneath the dense root system of velvetgrass and utilize the moisture there. Deervetch then increases in dominance by sending up shoots from the rhizomes. Possible explanations for the replacement of other species were not evident; however, there were some interesting correlations with the sequence. With each advancing stage the depletion trends became more consistent. Except for deervetch, which had the smallest number of roots, the root count decreased with each advancing stage. The decrease reflected an increase in the relative size of the roots.

Results of this study are applicable to forest regeneration problems. In terms of influence upon soil moisture, vine maple stands would be very competitive with tree seedlings. Velvetgrass and deervetch stands would also be competitive, deervetch perhaps more so at the deeper levels. Salal and Oregon-grape stands, on the other hand, would not be nearly as detrimental to tree seedling development.

22. 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.**

Plant succession on clearcut areas was studied on two experimental watersheds in the H.J. Andrews Experimental Forest. This paper reports on early trends in vegetation development on three units after clearcutting and slashburning. Very few invading plants were present at the first postlogging sampling; consequently, almost all vegetation was a remnant from the preexisting stand. The cover of all species was greatly decreased by logging. A marked recovery in the coverage of low shrubs and herbs began during the first growing season after slash burning. Some species present in small amounts in the stand before logging and burning had substantially increased their coverage. Species with more cover after slash burning than before disturbance included western dewberry (*Rubus ursinus*), star-flower (*Trientalis latifolia*), bedstraw (*Galium aparine*), and Oregon oxalis (*Oxalis oregana*). Herbaceous cover also increased for a number of invading species, including wood groundsel (*Senecio sylvaticus*), fireweed (*Epilobium angustifolium*), willow-herb (*Epilobium watsonii*), tall annual willow-herb (*Epilobium paniculatum*), western bleeding heart (*Dicentra formosa*), and pearly everlasting (*Anaphalis margaritacea*).

Disturbance history was at least as important as species composition of the undisturbed stand in determing plant distribution on these clearcut units. As plant succession advances, the influence of logging and slash burning disturbance will decrease and other site factors, such as soil characteristics and aspect, will become increasingly important in controlling plant cover and composition.

23. EISSENSTAT, D.M. 1980. **Water competition and animal damage in a grass-seeded Douglas-fir plantation. M.S. thesis, University of Idaho, Moscow, Idaho. 65 p.**

Plant water potentials of Douglas-fir (*Pseudotsuga menziesii*) were measured with a pressure bomb in a grass-seeded plantation in a western redcedar/myrtle boxwood (*Thuja plicata/Pachistima myrsinites*) habitat type. Planting of container-grown Douglas-fir seedlings in 1978 was followed by seeding of orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*), and red clover (*Trifolium pratense*) in a ratio of 5:3:2 at a rate of 25 lb/ac.

In 1979, both predawn and midday plant water potentials were significantly reduced by the grass treatment after a month with less than 12 mm of rain. No significant differences in plant water potential were detected in 1980. Douglas-fir seedling height, diameter, and leader-lateral length were significantly reduced in the grass treatment in 1980. Standing biomass within 18 cm of a Douglas-fir seedling was related to its plant water potential and growth parameters by canonical correlation. Only the seeded species and the shrubs were associated with increasing Douglas-fir moisture stress. Douglas-fir plant water potential could not be related to its growth parameters. Water is probably not the only limiting factor, or even the primary limiting factor, in regard to Douglas-fir seedling competition in the western redcedar/myrtle boxwood habitat type.

24. EISSENSTAT, D.M., and J.E. MITCHELL. 1983. **Effects of seeding grass and clover on growth and water potential of Douglas-fir seedlings. Forest Science 29:166-179.**

Container-grown seedlings of Douglas-fir (*Pseudotsuga menziesii*) were planted in 1978 on sites in northern Idaho in a red cedar/myrtle boxwood (*Thuja plicata/Pachistima myrsinites*) habitat type. Some plots were sown with 28 kg/ha of a mixture of orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*) and red clover (*Trifolium pratense*) seed. Water potential, growth rate, and total aboveground biomass of Douglas-fir seedlings were recorded in 1979 and 1980.

In 1979, predawn and midday water potential were reduced by grass during the two driest periods. No significant differences in water potential were detected in 1980. On northeast and southwest slope sites, sowing grass caused significant reductions in Douglas-fir diameter, height, and shoot growth, while growth on burned slopes was increased. Only grasses and shrubs were associated with increasing Douglas-fir moisture stress. Water potential could not be related to the growth parameters measured, and analysis of the data suggested that water probably is not the only (or primary) limiting factor in competition.

25. **ELLIOTT, K.J., and A.S. WHITE. 1987. Competitive effects of various grasses and forbs on ponderosa pine seedlings. Forest Science 33:356-366.**

Following an intense wildfire in June 1982 at a site 40 km north of Flagstaff, Arizona, 2-year-old seedlings of ponderosa pine (*Pinus ponderosa*) were planted on 100 plots in April 1983. Four grasses and two herbs (12 plots per treatment) were planted separately in July 1983, after summer rains had begun. Additional plots were allowed to develop natural competition or were weeded periodically to remove all competition. Predawn xylem water potential of the pine seedlings was measured biweekly during the 1983-1984 growing season. Extractable soil nitrogen was measured at the beginning and end of both seasons.

Concentrations of nitrate and ammonium in soil were significantly higher in the burned area than in an adjacent unburned area. Concentrations of these ions in grass treatment plots were significantly different at both the beginning and end of the growing season. Xylem water potential of the pines also differed between treatments. Competition for both moisture and available nitrogen apparently occurred and was reflected in differences in pine seedling growth.

26. **ELLISON, L., and W.R. HOUSTON. 1958. Production of herbaceous vegetation in openings and under canopies of western aspen. Ecology 39:337-345.**

Forests of quaking aspen (*Populus tremuloides*) support undergrowth capable of furnishing a great amount of cover and forage for wildlife and livestock. Curiously, much less vegetation is produced in openings than beneath the aspen stand. This study was designed to measure the productivity of herbaceous vegetation beneath aspen canopies and in adjacent openings where basic site factors appeared to be the same. Plots established at four sites in openings and under aspen canopy were seeded with mountain brome (*Bromus carinatus*), blue wildrye (*Elymus glaucus*), coneflower (*Rudbeckia occidentalis*), and cow-parsnip (*Heracleum lanatum*).

After 3 years, plots in the open were much more productive than untrenched plots under aspen, indicating that the potential for production is greater in openings than under aspen. The most consistently successful species was *Bromus*; the least, *Heracleum*. Trenched plots were much more productive than untrenched plots under aspen, which suggests that the principal factor in depressing yields under aspen is root competition. Utilization of forage by livestock is heavier in openings than under an aspen canopy. This difference in use intensity, together with the more adverse microclimatic effects associated with heavy grazing in openings, is believed to be responsible for the poorer production and species composition commonly noted in openings.

27. **EMBRY, R.S. 1971. Soil water availability in an Arizona mixed conifer clearcutting. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-206. 4 p.**

Measurements of soil water potentials on a site at 9,200 feet elevation, clearcut and partly sown with grass 4 years earlier, showed that the permanent wilting point (– 15 bars) was reached or exceeded only under grass. Soil water potentials were rarely lower than – 2 bars on scalped plots and were consistently highest on burned areas. The authors conclude that grassy sites are unfavorable to the establishment of conifer seedlings.

28. **FISKE, J.N. 1985. Estimating effects of competing plants on conifer growth and yield, and determining release needs. P. 129-143 *In* Proceedings, Sixth Forest Vegetation Management Conference, Redding, California. Forest Vegetation Management Conference, Redding, California.**

The author analyzed how various factors affect timber yield losses caused by early competition from other plants, how long competing plants must be controlled in order to achieve typical timber yield objectives, and the use of relative crown positions of potential crop trees and competing plants when determining release needs.

One factor affecting timber yield losses is the species composition and density of competing plants. Competing plants were classified as highly, moderately, or least competitive. Grasses and lupine were considered highly competitive. Yield reductions were computed for various timber types and competing plant species and densities. Heavy densities of grass reduced timber yield 30 to 70%, depending on timber type. The reduction from moderate densities of grass was negligible. In order to achieve Forest Service growth and yield objectives, grass and forbs should be reduced to no greater than medium density for at least 10 years after regeneration establishment (20 years in east-side stands of pine).

29. **FOURT, D.F., and W.H. HINSON. 1970. Water relations of tree crops: a comparison between Corsican pine and Douglas-fir in south-east England. Journal of Applied Ecology 7:295-309.**

The annual cycle of water movement was studied over five growing seasons in two adjacent semimature stands of Corsican pine (*Pinus nigra*) and Douglas-fir (*Pseudotsuga menziesii*) on deep porous soils in Bramshill Forest, Hampshire, England. Periods of soil water deficit in the stands were identified from records of gypsum-block resistance measurements of soil moisture tension. Rainfall over this period was equated with total evaporation calculated from climatic records. Water use by the two species was estimated, and the site factors affecting these estimates were examined.

It was concluded that Corsican pine, which dries the soil more deeply and intensely than Douglas-fir, uses more water during the period of deficit. The causes of these differences are not fully understood, but wind may interact with the distinctive canopy structure and leaf pattern of the species and thereby affect transpiration, although the rates of loss of intercepted rainfall seemed to be similar. Differences in the rate of uptake of water may be affected by rooting pattern and movement of water to the transpiring surfaces. The effects of the bracken understory and humus layers should also be considered.

30. **FROEMING, D.K. 1974. Herbage production and forest cover in the *Pseudotsuga menziesii-Symphoricarpos* habitat type of northern Idaho. M.S. thesis, University of Idaho, Moscow, Idaho. 39 p.**

Understory production of the Douglas-fir/snowberry (*Pseudotsuga menziesii / Symphoricarpos*) habitat type decreases as canopy cover increases. The changes are important in managing the forage available from the understory vegetation.

Total production declined continually but slowly as the canopy closed. The grasses and grass-like plants declined as the canopy began to close. At 30% canopy, their production increased as pinegrass (*Calamagrostis rubescens*) and blue bunch wheatgrass (*Agropyron spicatum*) increased, but again declined as the canopy closed from 50% to 70%. Forb production increased as the canopy closed to 50%, then declined as the canopy became more dense. Yields of shrubs declined to a 50% canopy and then increased.

The portion of the understory production usable by livestock depends on the palatability of the plants, the volumes present, and the type of grazing management. Total yield of usable herbage varied from over 300 lb/ac to about 100 lb/ac with increasing amounts of tree canopy cover.

31. GARY, H.L. 1968. **Soil temperatures under forest and grassland cover types in northern New Mexico. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-118. 11 p.**

Temperatures were recorded for 1 year at selected soil depths (1.5 to 112 inches) under aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and grassland types on north- and south-facing aspects at elevations from 9,990 to 11,150 feet. Plant cover type was more important than aspect, elevation, or snow cover in modifying soil temperature. Average annual temperature for the first 12 inches of soil ranged from 33.2° F on the north aspect under Engelmann spruce/subalpine fir at 11,150 feet to 40.8° F on the south aspect under aspen at 9,900 feet. Depth of freezing temperatures during the period of snow cover ranged from 1.5 to 3 feet.

32. GORDON, D.T., and E.E. BOWEN. 1978. **Herbs and brush on California red fir regeneration sites: a species and frequency sampling. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note PSW-329. 10 p.**

Species counts from 32 areas of felled and regenerated Shasta red fir (*Abies magnifica*) forest in northern California were compared with counts made in 1943 in virgin forest. The "loop" method of sampling was used for selecting sample plots. Fewer species were found in the regenerated areas, and fewer than 20% of species in logged areas were also found in virgin forest. Areas adjacent to logged areas were also sampled, but localized disturbance was judged to have affected plant populations already.

33. 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.**

The role of disturbance in seed germination and first-year survival of red alder (*Alnus rubra*) was studied over two growing seasons at four sites representing a climatic gradient within the central Coast Range of Oregon. Disturbance affected red alder seed germination and seedling establishment by altering the temperature and moisture properties of the seedbed, improving light conditions, and disrupting the activities of predators and pathogens.

Seedling emergence did not differ significantly between recent clearcuts and adjacent unlogged forests, but was higher on disturbed mineral soil seedbeds than on undisturbed organic seedbeds. In clearcuts, mean emergence on disturbed seedbeds ranged from 7 to 65% of viable seed sown and was positively correlated with spring soil moisture conditions across the climatic gradient. On disturbed forest seedbeds, emergence ranged from 23 to 57% and did not appear to be limited by soil moisture. Emergence on undisturbed seedbeds averaged less than 10%, except when seedbeds remained near saturation levels and light was not limiting.

In clearcuts, understory vegetation did not reduce germination substantially unless it was very dense or continuous. For example, germination averaged between 72 and 98.4% beneath sword-fern (*Polystichum munitum*), litter, and moss, compared to 95.4% on bare soil. Yet, under dense herbaceous vegetation, mean germination was only 41%, significantly lower than the 72% under sword-fern.

In the absence of forest disturbance, light conditions are important in controlling seed germination. Laboratory and field experiments demonstrated that germination is inhibited by light conditions in the forest understory. Broad-leaved trees such as red alder inhibit germination more than do conifers, because they filter out red light and increase the proportion of far-red light. Understory vegetation and litter layers have an additional inhibitory effect.

34. **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, British Columbia. Land Management Report 33. 180 p.**

Autecological information was gathered from published literature and personal contacts for 31 species that compete with the crop trees in British Columbia. The herbaceous species covered include lady-fern (*Athyrium filix-femina*), bluejoint (*Calamagrostis canadensis*), pinegrass (*Calamagrostis rubescens*), fireweed (*Epilobium angustifolium*), sword-fern (*Polystichum munitum*), and bracken fern (*Pteridium aquilinum*). For each species, information is provided on distribution; habitat; relations of climate, nutrients, water, light, and temperature; site conditions; phenology; reproduction; pests; competitive and beneficial effects on crop trees; and response to disturbance of management by canopy removal, fire, cutting, herbicides, and soil disturbance.

35. **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. dissertation, Oregon State University, Corvallis, Oregon. 185 p.**

Effects of tanoak on early growth, morphology, and physiology of Douglas-fir were studied to determine developmental characteristics of young stands and mechanisms of competition. Growth, leaf area, and biomass of Douglas-fir, tanoak, and shrubs and herbs were monitored for 6 years after establishing a gradient of tanoak cover with and without suppression of shrubs and herbs. Growth trajectories for Douglas-fir and tanoak were related to initial tanoak cover, a variable that can be predicted from inventory data from the preharvest stand. Suppression of shrub and herbaceous vegetation increased Douglas-fir growth, but only in the absence of tanoak.

Morphology, duration, and relative rates of growth of Douglas-fir were studied for three growing seasons to determine how the cumulative effects of competition caused tree size to vary. Tanoak competition reduced the size and number of buds, internodes, and needles for Douglas-fir shoots. In a given year, Douglas-fir growth was limited by competition in previous years through reduced potential growth (i.e., internode number for shoot growth and stem circumference for diameter growth) and by competition in the current year through reduced attainment of potential growth (i.e., expansion of internodes and basal area growth per unit stem circumference).

Mechanisms of competition were described by measuring variables of microclimate (air temperature, soil temperature, light, and soil water) and physiology (xylem pressure potential, conductance, and photosynthesis) in each of 18 consecutive months on Douglas-fir of different competitive status. Throughout the year, rates of photosynthesis in Douglas-fir shaded by tanoak were light-limited. During the growing season, photosynthesis was limited in both shaded and unshaded Douglas-fir in tanoak-dominated areas by elevated leaf temperature, lower relative humidities, and reduced soil water availability.

36. **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.**

Biomass and composition of 15 stands of red alder (*Alnus rubra*) on river-bottom sites in western Oregon were measured during August and early September, 1969. These stands were 2 to 64 years old. Biomass varied from 1,234 kg/ha for the youngest stand to 7,700 kg/ha in one of the older stands. Net productivity for the first 64 years was estimated as 97 kg/ha per year. Understory biomass was only 2.5% of the biomass of the alder overstory for similar stands. Composition varied considerably as age of the overstory increased. Succession from a grass/herb-dominated understory to a shrub/fern-dominated understory was quantified. The findings appear to support an earlier prediction that lands now dominated by red alder may be dominated by brushfields of salmonberry (*Rubus spectabilis*) in the future in the absence of a suitable source of conifer seed.

37. HERRING, H.G. 1970. **Soil moisture trends under three different cover conditions. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-114. 8 p.**

Summer soil-moisture trends were studied in central Washington for 3 years in (1) a second-growth stand of ponderosa pine (*Pinus ponderosa*), (2) a grassy opening, and (3) a clearcut plot in the pine stand. Soil moisture regimes in (1) and (2) were very similar, except after years of abnormally low winter rainfall. In (3), summer soil-moisture depletion initially was significantly lower, but further research is needed to determine how long this effect will last.

38. 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.**

Development of sprout clumps of Pacific madrone (*Arbutus menziesii*) of various initial densities and their effect on growth of Douglas-fir (*Pseudotsuga menziesii*) seedlings and understory vegetation were studied. Five years after density treatments, average leaf area index (LAI) of 9-year-old madrone sprouts ranged from 3.5 to 1.0 m^2/m^2 and total aboveground biomass from 25,630 to 8,390 kg/ha on the high- and low-density plots, respectively. Stem diameter of 9-year-old Douglas-fir was inversely related to madrone LAI and ranged from about 27 mm on the high-density plots to 54 mm in the absence of madrone. Diameter of Douglas-fir also grew significantly faster in the absence of madrone than in other treatments. An index of shrub, forb, and grass density was inversely related to madrone LAI, suggesting that understory species are quickly excluded from young madrone stands during secondary succession. Equations are provided relating the 5-year growth of 9-year-old Douglas-fir to measures of madrone density and seedling size made when the plantation was 5 years old.

39. HUNGERFORD, R.D. 1986. **Vegetation response to stand cultural operations on small stem lodgepole pine stands in Montana. P. 61-71 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

This paper describes procedures being developed to predict vegetative development after stand treatments of lodgepole pine (*Pinus contorta*) stands in Montana. Growth equations, based on 12 to 15 years of data, are used to describe growth of individual species or species groups, such as grasses and forbs or low shrubs. Community structure in vertical profiles is described on the basis of cover or leaf area. This procedure can be used to identify treatments that may reduce the abundance of unwanted species effectively.

40. ISAAC, L.A. 1940. **Vegetative succession following logging in the Douglas-fir region with special reference to fire. Journal of Forestry 38:716-721.**

After destruction by fire, the plant association in the Douglas-fir region goes through four distinct stages of succession before it reaches the climax type, unless succession is again interrupted by fire or logging. These stages are "moss-liverwort,", "weed-brush," "intolerant even-aged Douglas-fir" and "tolerant all-aged hemlock-true fir"; the last-named, so far as is known, persists. The weed-brush stage is most subject to fire, and successive fires do prolong and can perpetuate this stage. Colonies of exotic species upset natural succession in some localities because they are unpalatable and more vigorous than native species. Grazing tends to eliminate palatable species and favors others like the exotics, bracken, and brush; however, many introduced grasses have become naturalized and have improved grazing.

The underground parts of some ground cover species in virgin forest survive fires and form a minor part of the weed-brush stage; the remainder is made up of invading species, the most important of which are bracken (*Pteridium aquilinum*), fireweed (*Epilobium* spp.), blackberry (*Rubus ursinus*), and snowbrush (*Ceanothus velutinus*). Some species run their course and disappear, while others persist until they are crowded out by more vigorous brush cover and the oncoming forest. Light cover is beneficial to coniferous seedlings, but heavy cover is detrimental; the weed-brush stage often develops a density that practically prohibits forest regeneration.

41. JAMESON, D.A. 1967. **The relationship of tree overstory and herbaceous understory vegetation. Journal of Range Management 20:247-249.**

A good mathematical equation is very helpful in the study of the effect of trees on understory vegetation. This article presents an equation that fits overstory-understory data better than previously used equations.

42. JAMESON, D.A. 1968. **Species interactions of growth inhibitors in native plants of northern Arizona. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-113. 2 p.**

This study was conducted to determine the various interactions between some inhibitor and inhibited species. Extracts from six species were tested to determine their effects on radicle growth of newly germinated seeds. Inhibitor species included were Utah juniper (*Juniperus osteosperma*), ponderosa pine (*Pinus ponderosa*), pinyon pine (*P. edulis*), bottlebrush squirreltail (*Sitanion hystrix*), Arizona fescue (*Festuca arizonica*) and blue grama (*Bouteloua gracilis*). Test seeds were from bottlebrush squirreltail, blue grama, and ponderosa pine. Ponderosa pine, on the average, was less affected than the grasses. Arizona fescue was the grass most detrimental to ponderosa pine seedlings; blue grama had little effect. These findings may help explain causes of plant succession or changes in plant composition under different range management practices.

43. JOHNSON, B.R. 1986. **Influence of soil moisture, herbaceous competition, and small mammals on lodgepole pine (*Pinus contorta* var. *murrayana* [Grev. & Balf.] Engelm.) seedling establishment in Sierra Nevada meadows of California. Ph.D. dissertation, University of California, Davis, California. 94 p.**

To test the hypotheses that vegetative competition and high water tables prevent successful establishment of lodgepole pine in montane meadows in the California Sierra Nevada, 3-month-old lodgepole pine seedlings were transplanted into dry, mesic, and wet meadows in 1982 and 1983. Soil moisture was increased in dry and mesic meadows and decreased in wet meadows, in combination with reduction of vegetative competition and protection from small mammal grazers. Seedling response to abiotic factors was assessed with a stress/mortality index based on nongreen needles (NGN), which was linearly related to mortality.

Shade reduced mortality. In 1982, when soil water potential was between −0.2 and −0.3 MPa, NGN exceeded 0.6, but averaged 0.15 in plots without and with meadow vegetation. NGN and light exposure were correlated. Unusually high summer-long soil moisture in 1983 depressed NGN, which ranged from 0.15 to 0.40, compared to 0.15 to 0.80 in 1982. Survivorship after 3 months in protected control plots was 99% and 69% for 1983 and 1982 cohorts, respectively. No seedlings at ambient water tables survived in wet meadows after 3 years, compared to 17% in plots elevated 15 cm. First-season mortality from small mammals in unprotected control plots in 1982 was 8%, 37%, and 42% in dry, mesic and wet meadows, respectively, and in 1983 was 37%, 25% and 18%. After 3 years, 50% of the 1982 cohort had been killed by small mammals.

Given the apparent lack of competition and the tolerance of seedlings to moderately high water tables, small mammals are critical in excluding seedlings from meadows.

44. KIDD, F. 1982. Reduced growth of Douglas-fir in a grass-seeded plantation. Potlatch Corporation, Lewiston, Idaho. Forestry Technical Paper TP-82-2. 4 p.

A mixture of orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*), and red clover (*Trifolium pratense*) was broadcast-seeded (25 lb/ac) in June 1978, 2 months after container-grown Douglas-fir (*Pseudotsuga menziesii*) were planted. By 1980, seedling height, diameter, and leader-lateral length were significantly reduced by the grass treatment. Seedling survival was not affected. The herbaceous cover that grew around planted seedlings was a competitor for water; however, average 1979 minimum and maximum seedling water stress levels were not significantly different. This indicated that the increase in vegetation in seeded plots was not a moisture-limiting factor for Douglas-fir seedlings.

45. 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.

New conifer plantations on the west slopes of the Oregon Coast Range have numerous problems with competing shrubs and hardwoods. Grasses seed into clearcuts naturally in some areas. These areas had little or no woody vegetation growing in the clearcuts to shade planted conifers. Seeding of four different mixes of grass, legume, and fertilizer soon after burning and prior to planting retarded the invasion of thimbleberry (*Rubus parviflorus*) and red alder (*Alnus rubra*) for 5 years. Survival and growth of Douglas-fir (*Pseudotsuga menziesii*) was reduced in most cases, but not to the detriment of stand establishment. The growth losses that did occur were associated primarily with a particular grass species.

46. KOOIMAN, M., and Y.B. LINHART. 1986. Structure and change in herbaceous communities of four ecosystems in the Front Range, Colorado, U.S.A. Arctic and Alpine Research 18:97-110.

The structure of the herbaceous community in 1981 was compared with that in 1953 in four areas in the Front Range: (1) a ponderosa pine (*Pinus ponderosa*) stand at 2,200 m, where considerable mortality had occurred in the tree canopy; (2) a Douglas-fir (*Pseudotsuga menziesii*)/ponderosa pine stand at 2,600 m, where some changes in the tree population had occurred; (3) a quaking aspen (*Populus tremuloides*) stand at 3,050 m, where successional changes to Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) had occurred; and (4) a *Kobresia* meadow at 3,750 m. Changes in the frequency and composition of herbaceous species are discussed in relation to disturbances in the tree canopy.

47. KRAEMER, J.F. 1977. The long term effects of burning on plant succession. M.S. thesis, Oregon State University, Corvallis, Oregon. 134 p.

Succession of plants over 25 years was analyzed on clearcut areas in the western Cascades of Washington and Oregon. Thirty-three paired bumed and unburned plots were examined in 1975. Data were combined with records from prior examinations. Cover trends of six major brush species and five major herbaceous species were studied. Long term differences in plant succession between bumed and unburned sites were identified.

Trends in total brush and herbaceous cover were similar on burned and unburned sites. Total herbaceous cover peaked approximately 14 years after logging and declined rapidly in subsequent years. Total brush cover steadily increased during the 25 years. Increases in total brush cover were most rapid during the initial 14 years after logging.

Cover and occurrence of snowbrush (*Ceanothus velutinus*) were greater on burned plots, whereas rhododendron (*Rhododendron macrophyllum*), vine maple (*Acer circinatum*), and salal (*Gaultheria shallon*) formed more of the cover and occurred more frequently on unburned plots. Greater cover of residual species on unbumed sites was important in accounting for differences in successional trends. Variability between different plot pairs limited analyses. The author concludes that secondary succession in the western Cascades varies greatly with elevation and between geographic localities.

48. LARSON, M.M., and G.H. SCHUBERT. 1969. **Root competition between ponderosa pine seedlings and grass. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-54. 12 p.**

Grass is a common ground cover throughout the ponderosa pine (*Pinus ponderosa*) forests of the Southwest. Although grass is a valuable forage resource, its presence is definitely detrimental to initial establishment of coniferous reproduction. Certain grasses, however, seem to compete with pine seedlings less intensely than others. This difference in competitiveness is exemplified by two native bunchgrasses: Arizona fescue (*Festuca arizonica*), a strong competitor, and mountain muhly (*Muhlenbergia montana*), a mild competitor.

This paper reports on investigations of the tree-grass relationship on the Fort Valley Experimental Forest near Flagstaff, Arizona. The authors conclude that ponderosa pine should be planted only on grass-free areas. If grass is present, it must be killed or removed before trees are planted. Furthermore, since water is in short supply and pine roots reach out several feet, complete site preparation provides the best condition for tree survival and growth. Grass can be killed effectively with dalapon during the summer or removed with a bulldozer in the fall before planting. Until new research provides other altematives, dalapon or bulldozer treatment at the recommended times are the best methods to prepare planting areas.

49. LOEWENSTEIN, H., L.P. McCONNEL, and F.H. PITKIN. 1968. **Root development and survival of planted ponderosa pine seedlings as influenced by competing vegetation. University of Idaho Forest Experiment Station, Moscow, Idaho. Station Paper 5. 13 p.**

A radioactive tracer was used to study root development and survival of seedlings of ponderosa pine (*Pinus ponderosa*) planted (1) in undisturbed natural vegetation, or (2) on scalped patches of 12-, 36-, or 60-inch diameter. P^{32} was injected into the soil, and levels of radioactivity in the foliage of seedlings and competing plants were determined periodically in order to ascertain the presence of roots in the injection zone and the amount of absorption occurring. Survival after the first growing season was 48% on undisturbed microsites, but 77 to 86% on scalped areas. Data were obtained on rooting depth and extension of the pine seedlings, and also on competition from the native vegetation established at considerable distances (up to 2 feet) from the isotope placement sites.

50. LYON, L.J. 1966. **Initial vegetal development following prescribed burning of Douglas-fir in south-central Idaho. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah. Research Paper INT-29. 17 p.**

A prescribed fire was done on the Sawtooth National Forest for sanitation and site preparation. This gave an opportunity to study the postfire vegetal development and evaluate the postfire plant community as wildlife habitat. This paper is a report of the first 3 years of study.

Shortly after the prescribed fire, a new tree crop was planted and the roads were seeded with a domestic grass mixture, but no attempt was made to rehabilitate the bumed slopes. Natural vegetation recovered rapidly. Live ground cover returned to 27% in the first year and reached 69% in the second year, nearly double the live cover before the fire. Of more significance, perhaps, is the fact that the three plant species most important in this resurgence (*Moldavica parviflora, Ceanothus velutinus,* and *Iliamna rivularis*) were either uncommon or unrecorded in the prefire plant community. Since none of these species have windborne seeds, new plants must have come from seeds buried deep enough in the soil to survive a fire. In the second year, three species with light windborne seeds (*Lactuca serriola, Epilobium paniculatum,* and

E. alpinum) appeared in great numbers, and resprouts from *Arnica cordifolia* and *Ribes viscosissimum* were recorded in nearly half of the quadrats.

Perhaps the most important result of this fire was the rehabilitation of big game forage. Although shrubs in the second year had reached only 63% of the total crown volume recorded before the fire, forage values had at least doubled.

51. **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.**

The appearance of vegetation after forest site preparation was examined in 10 clearcut units in the western Oregon Coast Range. Site preparation in these units included scarification, slash buming, and chemical spraying. The ages of the clearcut units studied varied from 1 to 9 growing seasons for the scarification treatment, 2 to 10 for the slash burning treatment, and 2 to 6 for the spraying treatment. Herbaceous and shrub vegetation were characterized by biomass and cover measurements, together with the identification of the three principal species in each vegetation layer. In addition, the influence of the density of the previous conifer stand on the occurrence and abundance of shrubs after site preparation and the activity of browsers on both planted coniferous transplants and shrub stems were examined.

Results were evaluated in relation to the rate of reoccupancy of the site by herbaceous and shrub vegetation. This was used in an attempt to conceptualize the relative roles of both components of the system in the early stages of succession and to determine the strategies of these vegetation components as secondary plant succession progresses.

As a consequence of different intensities of site preparation, the vegetation on a clearcut unit is made up of several small vegetative units and is, therefore, variable in structure and composition. In this study, early successional trends were characterized by an increasing abundance of both herbaceous and shrub species in proportions related to the particular site conditions imposed by site preparation. In the initial stages of succession, microenvironmental factors under the influence of herbaceous species appeared to control the establishment of conifers. By the fourth year, increasing influence from the sprouting shrubs exerted a controlling influence on further succession.

Overall, composition of perennials, especially sprouting woody species, shortly after disturbance has a major effect on long-term community development. Selective consumption by deer and rodents can delete components of low abundance, such as conifers, during the early stages of succession. Choice of site-preparation method can affect both the composition and the density of woody cover and the apparent degree of animal use.

52. **MARCUM, L. 1971. Vegetal development in montane fir clearcuts in western Montana. M.S. thesis, University of Montana, Missoula, Montana. 122 p.**

Vegetative canopy coverages of six different clearcuts and their adjacent forest understories near Seeley Lake, Montana, were measured by species during the summer of 1969. All study sites were within the subalpine fir/myrtle boxwood (*Abies lasiocarpa/Pachistima myrsinites*) association; clearcuts varied in age but were as alike as possible in other characteristics. Vegetal development on the clearcuts was slow; total plant cover was approximately equal for the scarified and bumed areas. Seventeen years after the last disturbance, the vegetative canopy cover on both scarified and burned areas was only about 50% of that in the adjacent forest understory. Canopy coverage increased rapidly between the first and third year following disturbance, remained about the same from the third to the seventh year, and increased again between the seventh and seventeenth years. The number of species varied with the age of the site, as well as among understory, scarified, and bumed areas. The scarified areas had more species than the bumed areas at all sites (ages). Most cutover areas had more species than did the adjacent forest understory.

53. **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.**

Seedlings (2-0) of Douglas-fir (*Pseudotsuga menziesii*), unfertilized or fertilized with ammonium nitrate in October 1983, were planted in February 1984 near Corvallis, Oregon. Rye grass was grown on half the plots to induce water stress during the typical summer drought. Sucrose was applied to soil around each seedling to stimulate microbial growth and thus to immobilize nitrogen in the microbial biomass and create nitrogen stress in Douglas-fir. Fertilized seedlings had earlier budbreak, produced more shoot growth, and had higher relative growth rates, net assimilation rates and leaf area ratios than unfertilized seedlings. Grass significantly increased predawn moisture stress in both fertilized and unfertilized seedlings by early August. By September 3, unfertilized seedlings growing with grass were significantly more stressed than other seedlings. Fertilizer did not significantly affect concentrations of free amino acids and total nitrogen at the end of the growing season, but grass competition affected both nitrogen and carbohydrate chemistry.

54. **McCONNELL, B.R. 1971. Effect of ponderosa pine needle litter on grass seedling survival. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-155. 6 p.**

Survival rates of hard fescue (*Festuca ovina* var. *duriuscula*) were followed for 6 years on four different pine-needle treatment plots. Needle litter significantly affected initial survival of fescue seedlings, but subsequent losses undoubtedly resulted from the interaction of many factors.

55. **McCONNELL, B.R., and J.G. SMITH. 1965. Understory response three years after thinning pine. Journal of Range Management 18:129-132.**

Responses of understory vegetation to thinning of dense pine stands were analyzed in terms of the following changes in timber stand structure: (1) growing area per tree, (2) pine canopy, and (3) pine basal area. Responses of understory yield were also analyzed in terms of the three vegetal classes: grasses, forbs, and shrubs. Except for shrubs, which showed a nonsignificant response at the 5% level, results were essentially the same as for total yields. When pine canopy exceeded 45%, forbs showed a greater capacity to produce dry matter than did grasses; below 45%, grasses were the superior producers.

Tree spacing, tree canopy, and tree basal area are closely interrelated in their effects on understory vegetation. The bulk of these effects operate as climatic influences.

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

Grasses often hinder the establishment of conifers in plantations by preempting resources, chemically excluding natural seedlings (allelopathy), attracting insects and animals, and increasing the fire potential. Grasses generally are not desirable in conifer plantations less than 5 years old, but after 5 years, they can aid conifer seedling growth by physically and chemically excluding more competitive vegetation. In plantations over 5 years old on good sites with deep soils, grasses can be beneficial by excluding more deeply rooted shrubs. On poor sites with shallow soils, grasses and shrubs often compete throughout the profile, and no benefit accrues to conifer seedlings by introduction of grasses.

57. McLEAN, A., S.J. WIKEEM, and M.B. CLARK. 1986. Long-term effects of grass seeding and cattle grazing on a lodgepole pine clearcut. British Columbia Ministry of Forests, Victoria, British Columbia. Research Note 101. 21 p.

This study assesses the effects of cattle grazing and of seeding with a grass-legume mix on survival and growth of seedlings of lodgepole pine (*Pinus contorta* var. *latifolia*). Seedlings were planted on a clearcut in southern British Columbia in 1971. Pine growth parameters, tree and shrub density, understory botanical composition, and forage production were measured 13 years after the pine was planted and 12 years after the grass mix was sown.

Seeding did not affect pine diameter at breast height, basal area, or volume, but height was moderately suppressed. Grazing benefited pine growth, apparently by reducing competition from herbaceous vegetation. Pine growth was best on grazed but unseeded plots. Quaking aspen (*Populus tremuloides*) and willow (*Salix*) species had become major competitors with the pine saplings, and brush densities were high for all treatments. Seeded species occurred more frequently on the seeded plots, but their combined cover never exceeded 15%. Total forage production had declined only slightly since the first years following seeding, but production had shifted from grasses to shrubs and forbs.

Cattle grazing and seeding were compatible with regeneration of lodgepole pine. Factors contributing to this compatibility included good grazing management, which promoted even utilization of forage and minimized seedling injury, and establishment of lodgepole pine before grass seeding.

58. McMURTRIE, R., and L. WOLF. 1983. A model of competition between trees and grass for radiation, water and nutrients. Annals of Botany 52:449-458.

Conditions for coexistence of trees and grass were explored with a mathematical model describing plant competition for radiation, water and nutrients. The model described growth of both species in terms of key physiological processes (radiation interception, photosynthesis, respiration, grazing, litterfall, assimilate partitioning, nutrient uptake, and water use) and was used to analyze how species compete by depriving each other of resources essential for growth. Changes of growth parameters shifted species composition.

59. MOIR, W.H. 1965. The influence of ponderosa pine on herbaceous vegetation through shading, litter, and root competition. Ph.D. dissertation, Washington State University, Pullman, Washington. 57 p.

The relationship between tree overstory and herbaceous ground vegetation was studied in climax stands of the *Pinus ponderosa/Agropyron spicatum* association, Spokane County, Washington. Cover and vitality of ground vegetation were measured in 1-m^2 sample plots and related to the following microenvironmental attributes: total litter; light supply at the herbaceous level; soil moisture, nutrients, and soil organic matter; soil reaction; and abundance of pine roots.

The most pronounced changes in the environment of the ground vegetation during development of pine clusters were increasingly acidic soil, progressive contribution of pine organic matter to the soil, reduced nitrification rates, reduction of light to as low as 20% daylight, and increased evapotranspiration (suggested by soil moisture values at the latter part of the growing season). The importance of the various tree influences on ground vegetation was analysed with correlation and regression techniques that assumed a linear model for the sample information.

The tree influences were highly correlated to each other, so that the effect of any single factor on ground vegetation was difficult to assess. Tree clusters in early stages of development seemed most detrimental to the ground vegetation. Light and nitrate availability affected the vitality of the dominant grasses, as measured by inflorescence production. Both of these resources were limited at sites adjacent to or within sapling pine clusters. Herbaceous cover was also considerably reduced under these dense tree clusters. The abundance of small tree roots increased with continued development of the ponderosa pine and indicated the potential of root competition as a limiting mechanism. The unchecked development of the trees was accompanied by the trend toward total herbaceous suppression.

60. MOIR, W.H. 1966. **Influence of ponderosa pine on herbaceous vegetation. Ecology 47:1045-1048.**

Clusters of ponderosa pine (*Pinus ponderosa*) past the seedling stage adversely modified the herbaceous environment during their subsequent development, according to field and experimental data from Spokane, Washington. Herb suppression appeared early in the development of pine clusters, especially in the dense sapling stages. Increased light interception by the pine canopies and the poorer soil nitrogen supply under trees act together to reduce herb populations. This decline is indicated first by reduced inflorescence production in grass species and later by lessened canopy coverage of the ground vegetation. Continued tree development unchecked by fire or artificial thinning appears to lead to total or near-total herb suppression.

61. MUEGGLER, W.F. 1965. **Ecology of seral shrub communities in the cedar-hemlock zone of northern Idaho. Ecological Monographs 35:165-185.**

This study describes the relationships of shrub and herbaceous species in the cedar/western hemlock zone of northern Idaho to certain environmental factors. The relationships of 24 shrubs and 69 herbs to 16 environmental variables and to seral community classification are discussed. Numerous species were associated with the type of past disturbance, exposure, tree canopy, years since disturbance, latitude, and soil potassium level. Several species were associated with particular levels of total shrub cover, elevation, slope position, percent slope, soil parent material, and soil organic matter. Fewer species were associated with levels of soil phosphorus, pH, soil moisture capacity, and soil depth.

62. MUELLER, O.P. 1970. **Soil temperature regimes in a forested area on the northern Rockies. Soil Science 109:40-47.**

Soil temperatures at depths down to 60 inches were measured every month for a year at seven locations in western Montana. Soil temperature gradients at different seasons were plotted. Annual mean temperatures at 20 inches depth were higher than the annual mean air temperature under grass cover (with or without scattered conifers), but lower than annual mean air temperature under conifer stands.

63. NEUENSCHWANDER, L.F., H.L. OSBORNE, and P. MORGAN. 1986. **Integrating harvest practices and site-preparation activities to manage competing vegetation. P. 29-34 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

Predicting the competing vegetation before prescribing silvicultural treatment is essential to the integration of harvest practices and site preparation in managing competing vegetation. A conceptual model that predicts competing vegetation with multiple succession pathways for different site-preparation methods is presented. The model incorporates the critical influences affecting successional response to harvesting and site preparation for key competitor species. The critical successional processes are the determination of the initial flora, establishment, growth, and biotic interactions. The importance of severity of disturbance caused by harvest regeneration and site-preparation methods strongly affects the successional pathway. Several examples are given for tall shrubs, low shrubs, and grasses.

64. **NEWTON, M. 1964. The influence of herbaceous vegetation on coniferous seedling habitat in old field plantations. Ph.D. dissertation, Oregon State University, Corvallis, Oregon. 114 p.**

Plantation failures on abandoned pasturelands and old clearcuts are frequently associated with heavy stands of herbaceous vegetation. Competition from the vegetation has been described as the cause of mortality, but quantitative estimates were lacking until the recent development of selective chemicals, which makes it possible to create a range of vegetation conditions for study. This thesis analyzes the changes in some environmental factors (particularly moisture availability) that occur as functions of vegetation manipulation.

Aerially sprayed grassy south slopes near Corvallis, Oregon, with vegetation densities ranging from devegetated to fully stocked stands, were sampled intensively for moisture depletion in relation to the amount of vegetation surviving the herbicide. The rate of moisture depletion was a direct function of the amount of vegetation. Moisture loss caused by evaporation from the soil surface of devegetated plots was important in terms of tension only in the surface 6 inches. Abundant moisture remained in the root zones of planted seedlings below 6 inches. Fully vegetated plots were completely depleted of available moisture in the surface 36 inches by June 23, and depletion occurred at equal rates throughout the soil profile.

Mathematical models that predicted moisture depletion rates on the basis of vegetation, climate, and soil parameters were constructed. Models were derived for prediction of moisture availability at any given time on the basis of vegetation, drainage, and soil depth, and for prediction on a general basis of the moisture depletion rate likely to occur at any time and under any conditions of vegetation and soil, when qualified by meteorological data.

Drought conditions probably can be avoided for at least one season with proper evaluation and chemical amelioration of vegetation conditions.

65. **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.**

Growth of Douglas-fir on a well-drained moist site in the Oregon Coast Range was increased by controlling grasses and broadleaf herbs during the first 3 years after planting. Eight herbicide regimes were tested. Growth was greatest if weeds were controlled in the same growing season that tree seedlings were transplanted to the field; smaller increments came from second- and third-year weed control. Growth increases attributable to early weed control continued through the fifth year; thus, conditions during establishment apparently influenced later growth strongly. More soil water was available in plots with no herbaceous vegetation than in those with competing vegetation, and water stress was less in tree seedlings on plots without competition. Irrigation in the third year increased stem diameter of seedlings in that year but had no effect thereafter. Increases in average seedling stem volume 5 years after transplanting were linearly related to the difference in observed xylem potential during the first three growing seasons after transplanting and the xylem potential at which photosynthesis ceased (–2 MPa).

66. **NICHOLSON, A.C. 1989. Water relations, survival and growth of Douglas-fir seedlings at a pinegrass dominated site in the interior Douglas-fir zone of south-central British Columbia. M.S. thesis, Oregon State University, Corvallis, Oregon. 114 p.**

The impact of microclimate and vegetation on survival and growth of planted Douglas-fir (*Pseudotsuga menziesii*) was studied at a clearcut dominated by pinegrass (*Calamagrostis rubescens*) in the interior Douglas-fir zone of south-central British Columbia. The study focused on (1) the water balance of the site, (2) the response of Douglas-fir and pinegrass to moisture deficits, and (3) the influence of environmental factors and vegetation on Douglas-fir survival and growth.

After three growing seasons, survival of Douglas-fir in the absence of pinegrass was 43%. Mortality resulted from a variety of factors, including drought, frost, and rodent damage. Poor seedling quality at the time of planting was also suspected to have contributed to mortality. In the presence of the native vegetation, Douglas-fir seedling growth was reduced and mortality increased. Reducing the leaf area index around the seedlings to less than 0.5 effectively improved seedling performance. Removing all vegetation immediately adjacent to a seedling was preferable to partial removal.

Rapid growth of pinegrass early in the growing season, when moisture is least limiting, gave it a competitive advantage over Douglas-fir in relative growth rate. Soil temperatures beneath pinegrass-dominated vegetation were cooler and warmed more slowly in the spring than they did beneath bare soil. Thus, native vegetation may restrict root growth of Douglas-fir by influencing soil temperature.

Although the pattern and timing of soil moisture depletion differed in each of the three growing seasons, measurements of total evapotranspiration over the growing season were similar. Pinegrass transpiration appears to be responsible for removing most of the water from below 10 cm. Pinegrass, in fact, played a major role in the water balance of the site.

67. 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.**

Soil water potential and moisture stress and growth of Douglas-fir (*Pseudotsuga menziesii*) were studied on a droughty 2-ha site in southwest Oregon. Pacific madrone (*Arbutus menziesii*) and associated shrub and herbaceous vegetation were thinned to represent the following conditions: high-density madrone (H), associated shrubs and herbs controlled; medium-density madrone (M), shrubs and herbs controlled; low-density madrone (L), shrubs and herbs controlled; no madrone (N), shrubs and herbs controlled; and no madrone (U), shrubs and herbs predominate.

Soil water potential at a depth of 0 to 30 cm was consistently higher in treatment N than in all other treatments; in 1987 this difference was significant ($P < 0.025$). Average soil water potential in treatment U reached –1.5 MPa (permanent wilting point) between June and July in both years of the study, whereas in the other treatments that level was never reached. Soil water conditions were also relatively severe in treatment H.

Predawn plant moisture stress of Douglas-fir was significantly less in treatment N than in all other treatments. Seasonal moisture stress relief of Douglas-fir was significantly related to madrone leaf area index and was greatest in treatment N. Seasonal moisture stress relief was also significantly correlated with leaf area index. Linear relationships between both predawn and midday plant moisture stress and soil water potential were highly significant for Douglas-fir and madrone.

Conditions for maximum Douglas-fir growth occurred in treatment N, in which all madrone and associated vegetation were controlled. Average diameter growth of Douglas-fir was greatest in treatment N (although not significantly different from that in treatment U) and least in treatment H. In 1987, growth of stem diameter, basal area, and volume in Douglas-fir was strongly related to seasonal moisture stress relief, madrone leaf area index and, to a lesser extent, seasonal tension relief.

68. PEARSON, G.A. 1934. **Grass, pine seedlings and grazing. Journal of Forestry 32:545-555.**

Early studies of ponderosa pine (*Pinus ponderosa*) reproduction in the Southwest emphasized the value of protection of young seedlings against sun, wind and cold. Shade by trees, grass, logs and other objects was thought to be beneficial, if not indispensable. Later, the idea was advanced that such benefits as are derived from cover operate mainly through soil improvement, and that shelter of the seedlings themselves is rarely needed or may be harmful. The information presented in this article supports the latter viewpoint.

69. **PEARSON, G.A. 1942. Herbaceous vegetation as a factor in natural regeneration of ponderosa pine in the Southwest. Ecological Monographs 12:315-338.**

In the ponderosa pine (*Pinus ponderosa*) forests of the southwestern U.S., grasses predominate on the heavier soils. These grasses compete strongly with pine seedlings in the initial stages of root development, when moisture is required from the upper soil layers. The intensity of competition varies with the growth habits of different grasses; Arizona fescue (*Festuca arizonica*) is the most aggressive, as it grows during May and June, when precipitation is at a minimum. Survival and growth of seedlings were best on experimental plots that were denuded and kept free of all competing vegetation. Soil moisture appeared to be the most important determinant of results under different treatments, while light appeared to be an important secondary factor.

Controlled grazing aids pine reproduction, but grazing should not continue to the point of denudation.

70. **PETERSEN, T.D. 1988. Effects of interference from *Calamagrostis rubescens* on size distributions in stands of *Pinus ponderosa*. Journal of Applied Ecology 25:265-272.**

Ponderosa pine was grown as widely spaced trees in a hexazinone-treated monoculture and in mixture with a grass, pinegrass (*Calamagrostis rubescens*), for four growing seasons. The study was conducted on a forest site in northwest Montana. Interference from pinegrass reduced biomass production of ponderosa pine. Weights of foliage, above-ground woody tissue, and roots were respectively 430%, 450%, and 460% greater in the monoculture than in the mixture. The frequency distribution of stem volumes in the monoculture became positively skewed after two growing seasons. Therefore, dominance and suppression associated with above-ground competition between trees are not necessary for development of skewed size distributions in stands of ponderosa pine. The size distribution became positively skewed more quickly and remained more highly skewed in the mixture than in the monoculture. Interference from pinegrass decreased the mean growth rate of stem volume in ponderosa pine, regardless of initial size class, but simultaneously increased the relative variation in growth rate. The greater variation in growth rate more than offset the tendency of slower-growing stands to have more symmetrical size distributions.

71. **PETERSEN, T.D., and B.D. MAXWELL. 1987. Water stress of *Pinus ponderosa* in relation to foliage density of neighboring plants. Canadian Journal of Forest Research 17:1620-1622.**

A continuous gradient of foliage of competing species was created on two sites in northwestern Montana by applying hexazinone. Seedlings were then planted in May 1984. Needle water potential during early summer appeared to be related to transplanting stress. In late summer, soil water content decreased linearly in relation to the amount of foliage of herbs and shrubs. Predawn needle water potential of pine seedlings ranged from -0.5 MPa when competitor foliage was almost absent to less than -3.0 MPa when such foliage was more extensive. Even a small amount of competing foliage increased water stress in the pine seedlings. Differences between the sites illustrated why silvicultural treatments to control competing plants may have inconsistent effects on pine survival and growth.

72. **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.**

Snowbrush (*Ceanothus velutinus*) and other weeds, such as fireweed (*Epilobium angustifolium*), trailing blackberry (*Rubus ursinus*), and bracken fern (*Pteridium aquilinum*), suppressed growth of Douglas-fir (*Pseudotsuga menziesii*) in plantations in the central Cascades of western Oregon. Increases in stem volume of Douglas-fir after 4 years were greatest when all competing vegetation had been controlled for one growing season with herbicides.

Snowbrush may compete with Douglas-fir by depleting soil moisture. The mechanism by which forbs suppress the growth of Douglas-fir is less evident. Competition for nutrients or perhaps allelopathic inhibition of conifers, rather than competition for water, may account for the better growth of Douglas-fir when free from forbs. In order to achieve the maximum reduction in rotation time, Douglas-fir should be released at an early age. Forbs can negate the potential benefits of release from shrubs and should be controlled concurrently with shrubs to promote the maximum growth of Douglas-fir.

73. 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.**

Stem dimensions for two age groups of Douglas-fir (*Pseudotsuga menziesii*) growing in the central Cascade Mountains of western Oregon were related to water stress and the amount of interference from dense snowbrush (*Ceanothus velutinus*) and forbs 8 years earlier. In 1978, three regimes were established in four 5-year-old and four 10-year-old stands. Individual trees in each stand were either untreated (controls) or received one of two herbicide treatments: partial treatment (snowbrush eliminated) or a complete treatment (both shrubs and forbs eliminated). Where snowbrush was growing with forbs, soil water potential during late summer 1979 was <–1.5 MPa at 10-, 40-, and 100-cm depths. In the absence of shrubs and forbs, soil water potential at 100 cm was near field capacity throughout the 1979 growing season. In the four 5-year-old stands and in two of the 10-year-old stands, predawn stem water potential of Douglas-fir during late summer was significantly lower in trees competing with snowbrush and forbs than in either trees without competitors or trees competing with forbs. By 1986, Douglas-fir stems were 2 to 6 cm larger in basal diameter and 1 to 2 m taller without competitors. Interference from snowbrush and forbs had a greater effect on stem size of the younger trees. The correlation between growth and water stress suggests that interspecific competition for soil water during summer drought is a factor limiting stemwood production.

74. PIERSON, E.A.K. 1988. **Limits to the distribution of *Bromus tectorum* in forests of eastern Washington and northern Idaho. Ph.D. dissertation, Washington State University, Pullman, Washington. 145 p.**

The invasive alien cheatgrass (*Bromus tectorum*) is uncommon in undisturbed forests of the Intermountain West. The demography of the grass was compared for 4 years among sown populations in four forest habitat types. Recruitment ranged from 26 to 98% in all sites. Recruitment and survivorship were greater in the three lower elevation forests (*Pinus ponderosa*, *Pseudotsuga menziesii*, and *Abies grandis*) than in the forest of highest elevation (*Thuja plicata*). Biomass and seed production decreased to zero in forests with increasing elevation; net reproduction in all forests was <1.

The effect of gaps in the overstory and understory on recruitment and reproduction of cheatgrass was examined by sowing cheatgrass into variously aged forest stands. Recruitment, survival, and reproduction in forested and clearcut stands in the *Pinus* and *Pseudotsuga* sites were not significantly different. Recruitment, survivorship, and reproduction of cheatgrass were higher in understory openings under mature canopy than in undisturbed plots in *Pinus* forests, but not in the *Abies* forest.

The effect of light on photosynthetic rate, growth, and tolerance to grazing was examined in cheatgrass grown either in full sunlight or in 60%, 80%, or 90% attenuated light. Plants grown in shade maintained the capacity for high photosynthetic rates at high light levels. Plants grown in full sunlight had more root biomass, more tiller, more leaves, greater leaf area, and greater total biomass than plants in shade. In contrast, shaded plants allocated more of their total production to shoot growth. Plants grown in full sunlight replaced a greater proportion of biomass lost through grazing than did shaded plants.

Greatly reduced growth in shade and intolerance of the shortened growing season in forests are largely responsible for the restriction of cheatgrass in mature forests and its success in gaps and clearings.

75. 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.**

Chemical control of grasses in plantations of Douglas-fir (*Pseudotsuga menziesii*) predisposes the sites to heavy infestations of forbs and forbs plus annual grasses in the subsequent several years. This thesis attempts to answer the question "To what extent can these infestations justifiably be ignored?" in terms of their effects on soil moisture.

Data for this study came from observations and experimentation on a series of existing herbicide trial plots in a grassy meadow in the Oregon Coast Range. The vegetative covers of the plots reflected histories of 0 to 3 years of herbicide treatment and could be classified into (1) unvegetated or lightly vegetated with forbs, (2) moderate to dense pure forbs, (3) dense forbs plus annual grasses, and (4) heavy bent grass (*Agrostis tenuis*).

Early in the season, bent grass made heavy demands on the soil moisture in the upper profile but only moderate demands on moisture in the lower profile, a pattern consistent with its aestivating and rooting characteristics. Moderate to dense pure forbs made relatively light demands on the upper profile early in the season, but later made heavy use of moisture at all levels in the profile. The forb/annual grass mixture was the most demanding of all. It caused heavy early season moisture withdrawal from the upper profile, coupled with sustained moisture depletion of the lower profile. Again, this pattern was consistent with the phenological and rooting habits of the vegetation.

A substantial amount of water was not transpired because of weed control but was eventually lost, probably through increased surface evaporation and unsaturated flow. Nevertheless, although weed control may have made available to the trees only a small amount of the moisture saved from transpirational loss, such control is of major importance in the relief of tree moisture stress.

Bent grass, forbs, and forb/annual grass mixtures are hostile ecosystems for the establishment of Douglas-fir in areas characterized by Mediterranean summers. It would therefore seem desirable (and perhaps economically justifiable) to prolong the period of complete or semi-complete herbaceous weed control in young conifer plantations being established under these conditions.

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

The experimental area was the focus of a continuing and expanding series of experiments begun in 1968 to study the interactions between young trees and old-field herbaceous weed communities. The principal objective of the experiments was to discover opportunities that herbicides can provide to favor the growing stock by environmental manipulation. In his Master's thesis, the author investigated how modification of plant communities affected site resource allocation, especially availability of soil moisture to trees. This study extends that work and quantifies tree response to this environmental manipulation, both in terms of its transient effect on tree moisture stress and its permanent effects, expressed in tree growth.

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

Survival and growth of young transplants of Douglas-fir (*Pseudotsuga menziesii*) in the warm, dry summer climate of Oregon are heavily influenced by competition from grasses and other herbaceous weeds. The ephemeral increase in available soil moisture that resulted from weed control reduced tree moisture stress in the summer. This not only resulted in immediately increased growth, but also had significant positive effects on tree growth for several years following, hastening the onset of exponential growth and thus shortening crop rotation.

78. PYKE, D.A., and B.A. ZAMORA. 1982. **Relationships between overstory structure and understory production in the grand fir/myrtle boxwood habitat type of northcentral Idaho. Journal of Range Management 35:769-773.**

Relationships between overstory structure and understory current-year production were studied on 20 undisturbed sites of the grand fir/myrtle boxwood (*Abies grandis/Pachistima myrsinites*) habitat type in the Clearwater Mountains of northcentral Idaho. Understory production was divided into 4 vegetation classes: (1) shrubs, (2) forbs, (3) graminoids and (4) total production. Regression models predicting current-year production of each understory vegetation class were developed with all possible combinations of overstory parameters used as independent variables.

Canopy coverage and the sum of tree diameters were the best indices of understory production. Canopy coverage was most significantly correlated with total understory production and shrub production. Canopy coverage and the sum of tree diameters were the overstory parameters most significantly correlated with forb production. Graminoid production was not significantly correlated to any of the overstory parameters measured. Basal area, tree density, and stand height were not statistically related to understory production.

79. RIETVELD, W.J. 1975. **Phytotoxic grass residues reduce germination and initial root growth of ponderosa pine. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-153. 15 p.**

Extracts of green foliage of Arizona fescue (*Festuca arizonica*) and mountain muhly (*Muhlenbergia montana*) significantly reduced germination of ponderosa pine (*Pinus ponderosa*) seeds, retarded speed of elongation, and reduced mean radicle length. Three possible routes of release of the inhibitor were investigated: (1) leaching from live foliage, (2) root exudation, and (3) overwinter leaching from dead residues. The principal route remains uncertain. The ecological implications of the inhibitory substance are discussed.

80. ROBINSON, A.F., Jr. 1967. **The influence of tree cover and shade pattern upon the distribution of understory plants in ponderosa pine stands of central Oregon. M.A. thesis, Oregon State University, Corvallis, Oregon. 77 p.**

Seven sites with uniform topography and soil were selected within a self-perpetuating forest of ponderosa pine (*Pinus ponderosa*) on the eastern flank of the central Oregon Cascades. Two statistical methods, the Dfd index and Cole's index, were used to correlate the distributional pattern of understory species to overhead tree cover, shrub cover, and shade. Cole's index appeared to be a more sensitive tool for this study.

Ten of the 16 herbaceous species observed showed apparent affinities for specific microhabitats within the stand. Plot location, shade, overhead vertical crown cover, and shrub cover influenced the distribution of herbaceous species within the plot. Species in mesic plots showed a weak affinity for cover, but those on xeric plots showed a strong affinity for cover. Some insight into the ecological performance of the species was gained in regard to insolation. Usually the plot location coincided with the affinity of the species for an insolation class. Species occurring mainly on the mesic end of the gradient showed an affinity for deep shade (*Lupinus caudatus, Fragaria virginiana, Trientalis latifolia,* and *Pteridium aquilinum*). Species occurring mainly on the xeric end of the gradient showed an affinity for high insolation (*Viola purpurea, Carex inops,* and *Madia minima*). Five species showed some affinity for moderate insolation (*Clarkia rhomboidea, Eriogonum umbellatum, Kelloggia galioides, Mimulus nanus,* and *Stipa occidentalis*), but correlation with plot location was less clear. Four species (*Festuca idahoensis, Sitanion hystrix, Achillea millefolium,* and *Lathyrus lanswertii*) were not restricted to any part of the gradient.

81. **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.**

Modification of air and soil temperature by four successional dominant species was investigated during the summers of 1961 and 1962 on the Marys Peak watershed. A consistent pattern of succession occurs on bumed Douglas-fir (*Pseudotsuga menziesii*) clearcuts on the watershed. The early stages of succession are characteristically dominated by wood groundsel (*Senecio sylvaticus*) in the second year after cutting, bull thistle (*Cirsium vulgare*) in the third, and velvetgrass (*Holcus lanatus*) and deervetch (*Lotus stipularis*) for several years following.

Maximum air temperature 1.5 inches above the ground and soil temperatures 3 inches below the surface were measured in each of the four dominant species. All temperatures in the vegetated areas were compared to those in associated areas of comparable exposure that had been denuded of all plants.

The physical form of the species studied was related to maximum air temperature. Deervetch is characterized by a dense canopy of leaves 1 or 2 feet above the ground. This canopy reduces light sharply at the soil surface, causing maximum air temperatures about 7° below those on similar bare-ground areas. Velvetgrass has no canopy, but rather a dense mat of grass leaves at the soil surface. This species raised, rather than lowered, maximum air temperature relative to bare-ground areas; maximum air temperatures averaged 5° above those on bare ground. Groundsel and bull thistle, which have similar life forms and similar temperature environments, fell between the extremes found in deervetch and velvetgrass. Both species depressed maximum air temperatures about 5°. Soil temperatures were always cooler under vegetation than under bare ground. The amount of temperature difference seemed to be correlated with the amount of plant material available as a heat-insulating layer.

The early stages of plant succession (bull thistle and wood groundsel) create a highly changeable temperature environment over the clearcut as annuals and biennials shift populations rapidly. The later stages of succession, made up mostly of perennials (velvetgrass and deervetch), are relatively stable. Any species attempting to become established after clearcutting will be subjected to different temperature environments, depending on how soon it germinates after the clearcut is made. Tree seedlings such as Douglas-fir probably have the best chance of survival when planted within 3 years after clearcutting.

82. **ROBINSON, M.C. 1968. Growth and replacement patterns occurring among selected dominant species associated with plant succession on Douglas-fir clear-cuts. Ph.D. dissertation, Oregon State University, Corvallis, Oregon. 84 p.**

Growth and replacement patterns of four successionally important species occurring on Douglas-fir (*Pseudotsuga menziesii*) clearcuts were investigated from September 1964 to June 1967. The study was carried out on the Marys Peak watershed near Corvallis, Oregon. Species used in the study included velvetgrass (*Holcus lanatus*), tansy ragwort (*Senecio jacobaea*), big deervetch (*Lotus crassifolius* var. *subglaber*), and Cascade Oregon grape (*Berberis nervosa*). Each of 24 transects on three separate clearcuts was sampled 11 times over 3 years to detect changes in vegetational structure and composition.

In general, the species studied grew better and more vigorously in mixed stands than in pure stands. Competition did not appear to be important in species replacement during the early stages of plant succession. Behavior of a species on a young clearcut may depend more on its own ecology and changing soil factors than on competition from other species. Vegetation on clearcuts may often be mosaic-like rather than homogeneous, made up of many small vegetational units that differ in both structure and composition. Much further study on the ecology of successionally important species is recommended to elucidate plant succession of Douglas-fir clearcuts.

83. ROY, D.F. 1953. **Effects of ground cover and class of planting stock on survival of transplants in the eastside pine type of California. USDA Forest Service, California Forest and Range Experiment Station, Berkeley, California. Research Note 87. 6 p.**

Twelve hundred ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*) were planted on various aspects of recently cutover land at the Blacks Mountain Experimental Forest. The surface conditions were classified after planting as (1) bare mineral soil, (2) slash, (3) stones, (4) squaw carpet (*Ceanothus prostratus*), (5) other shrubs, and (6) grass or sedge (*Carex rossii*). Survival of planting stock was strongly affected by vegetation, logging slash, and stoniness of the ground where the trees were planted. On the average, tree survival was best on bare soil that had no stones, second best under slash, third on open stony ground, fourth in shrub cover, fifth in grass and sedge, and least in squaw carpet. The differences in survival appeared to be associated chiefly with differences in soil moisture supply.

84. SCHIMKE, H.E., L.R. GREEN, and D. HEAVILIN. 1970. **Perennial grasses reduce woody plant seedlings — on mixed conifer fuel break. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note PSW-203. 3 p.**

After initial clearing, parts of a fuelbreak on the Stanislaus National Forest in central California were planted to perennial grasses; adjacent parts were not. After 5 years, the perennials had reduced the number of woody plant seedlings by a factor of 8, height of seedlings by 50%, and amount of annual plant ground cover by 33%. Without perennial grass, the site would be reoccupied by woody plants in a very few years.

85. 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.**

Species diversity and community composition were studied at 23 sites on similar western hemlock/Douglas-fir (*Tsuga heterophylla*/*Pseudotsuga menziesii*) forest habitats. Sites were located in undisturbed old-growth stands and in stands at 2, 5, 10, 15, 20, 30, and 40 years after clearcutting, broadcast burning, and planting with Douglas-fir. Vegetation was sampled with three 5 x 60 m transects at each site.

Invading herbs, then invading and residual shrubs, and finally conifers dominated through the first 30 years. Late seral species, which accounted for 99% of cover in old-growth stands, were nearly eliminated immediately following disturbance, but accounted for almost 40% of vegetative cover after 5 years, 66% after 10 years, 83% after 20 years, and 97% at 40 years. After an initial drop following disturbance, species diversity trended weakly upward, with heterogeneity peaking at 15 years and richness at 20 years. This initially high diversity (higher than that of old-growth stands) was short-lived. After the tree canopy closed, species diversity declined, reaching its lowest values at 40 years. Only two species were eradicated after disturbance, both mycotrophs.

Pacific Northwest old-growth forests are relatively poor in species, but moderately high in heterogeneity values.

86. SEVERSON, K.E., and J.J. KRANZ. 1976. **Understory production not predictable from aspen basal area or density. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station., Fort Collins, Colorado. Research Note RM-314. 4 p.**

Analysis of effects of basal area and density of aspen (*Populus tremuloides*) on production of understory vegetation revealed no useful predictive relationships from the model log Y = a + bX. However, as the proportion of basal area in ponderosa pine (*Pinus ponderosa*) increased in aspen-pine stands, understory production declined predictably. Root biomass, total biomass, and/or growth rate of aspen may be more closely related than measures of aspen overstory to understory production.

87. **SIMARD, S., and A. NICHOLSON. 1990. Balancing the positive and negative effects of non-crop plants on conifers: pinegrass, fireweed, Sitka alder, and paper birch — friend and foe. P. 45-48 *In* Vegetation Management: An Integrated Approach, Proceedings of the Fourth Annual Vegetation Management Workshop, Vancouver, British Columbia. E. Hamilton, ed. Forestry Canada and British Columbia Ministry of Forests, Victoria, British Columbia. FRDA Report 109.**

Noncrop plants are usually managed to reduce their negative effects on survival and growth of conifers. Noncrop plants can compete for resources, alter environmental conditions, or cause physical damage. Under some conditions, however, noncrop plants should be managed to enhance their positive characteristics, which include nutrient cycling, nitrogen fixation and frost protection.

Pinegrass (*Calamagrostis rubescens*) exploits moisture at the expense of conifer seedlings because of rapid, early growth and high water use. Pinegrass cover also reduces heat transfer into the soil during the day, resulting in decreased soil temperatures that may impede conifer root growth in early spring. Tall, dense canopies of fireweed (*Epilobium angustifolium*) may provide protection from radiation frost and trap warm air. However, dense canopies of fireweed may press and bend seedlings in the fall.

88. **SIMARD, S.W. 1989. Competition among lodgepole pine seedlings and plant species in a Sitka alder-dominated shrub community in the southern interior of British Columbia. M.S. thesis, Oregon State University, Corvallis, Oregon. 143 p.**

Sitka alder (*Alnus sinuata*) dominates many lodgepole pine (*Pinus contorta* var. *latifolia*) sites following clearcutting in the montane spruce zone of the southern interior of British Columbia. The objectives of this study were to examine the effects of the shrub community dominated by Sitka alder on the performance of lodgepole pine and on levels of environmental resources and conditions. Competitive interactions were examined in two studies: (1) among 2-year-old planted seedlings and plant species in various experimentally created shrub densities (0 to 2514 clumps/ha) and herb covers (0 to 100%), and (2) among 8-year-old naturally regenerated saplings and plant species in an undisturbed community.

In the first study, survival of seedlings averaged across the experimentally created competition levels was 86% 2 years after planting. The main causes of mortality were drought and browsing by hares (*Lepus* spp.). Survival rate was not significantly affected by shrub and herb densities, but was lowest where all vegetation had been removed. Seedling mortality in the total-removal treatment may have resulted from high radiation loads and low moisture availability immediately after planting.

Mean seedling size in the plantation was negatively affected by shrub and herb density. Stem diameter, the most responsive performance measure, was 25% smaller on average when seedlings were growing among maximum shrub and herb densities than when they were growing free of competition. Height, in contrast, increased as shrub and herb densities increased. The decrease in diameter and increase in height in response to increasing vegetative competition reflected patterns in resource (particularly carbon) allocation.

In the second study, two vegetation types were identified in a 10-year-old community. Type I was dominated by lodgepole pine and pinegrass (*Calamagrostis rubescens*), while type II was dominated by Sitka alder, thimbleberry (*Rubus parviflorus*), and black huckleberry (*Vaccinium membranaceum*). The size of individual pine saplings was affected more negatively by neighboring plants in type II than type I.

89. SIMS, H.P., and D. MUELLER-DOMBOIS. 1968. Effect of grass competition and depth to water table on height growth of coniferous tree seedlings. Ecology 49:597-603.

Seedlings of jack pine (*Pinus banksiana*), red pine (*P. resinosa*), white spruce (*Picea glauca*), and black spruce (*P. mariana*) were grown in two sloping tanks in a greenhouse in combination with three grasses on (1) a loamy sand and (2) a sand. With an equal water supply, much greater total vegetative production was achieved in (1), but this did not result in greater tree seedling heights. Instead, when the water table lay at the optimum depth for the trees on (1) (as indicated by their growth without grass competition in an earlier experiment), the grasses grew more vigorously and suppressed them. In (2), however, seedling height trends varied little from those previously observed in the experiment without grasses. Characteristics of competition are discussed in relation to patterns of root and shoot growth of tree seedlings and grasses.

90. STAHELIN, R. 1943. Factors influencing the natural restocking of high altitude burns by coniferous trees in the central Rocky Mountains. Ecology 24:19-30.

A survey was conducted in eight areas to determine the status of natural coniferous regeneration on bumed areas in the subalpine forest zone. The sudden destruction of the climax association by forest fires gives rise to establishment of a fire subclimax of aspen (*Populus tremuloides*) and lodgepole pine (*Pinus contorta*), as well as to invasion by plants of the *Carex-Poa* association. Where lodgepole pine was represented in the original stand, enough seeds escaped destruction to form a stand of seed trees that will re-establish a lodgepole pine cover within 50 to 100 years, even if aspen or grass temporarily becomes dominant immediately after the fire. Sedges, grasses, and other species characteristic of the subalpine grassland build up a dense turf on burned areas above the distribution of lodgepole pine and aspen. This sod constitutes an effective barrier to the establishment of coniferous seedlings, and indications are that this herbaceous cover will be able to maintain itself for centuries.

In general, areas supporting more than 10 well-scattered seed trees per acre will revert to a coniferous stand on all sites within 50 years after a forest fire, except when grass is dense. Grassy areas with fewer than 10 seed trees per acre must usually be planted in order to re-establish a coniferous cover.

91. 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.

Typical variation in vegetation following slash burning is shown by comparison of paired photographs of two areas in the same locality. The second growing season after burning, groundsel (*Senecio* spp.) formed a much heavier cover on burn B than on burn A. During the fourth growing season, several herbaceous species grew on burn A, while bum B was invaded by brush. Thirteen years after the slash fire, the two pairs showed marked differences; conifers were well established on A, while heavy brush covered B. These variations in vegetation following slash fires illustrate the predicament faced by the forest land manager when deciding whether or not to use slash burning as a management tool.

92. STEWART, R.E. 1975. Allelopathic potential of western bracken. Journal of Chemical Ecology 1:161-169.

In laboratory studies, water-soluble extracts from senescent fronds of western bracken (*Pteridium aquilinum* var. *pubescens*) reduced germination of western thimbleberry (*Rubus parviflorus*) and delayed germination of salmonberry (*R. spectabilis*), but did not affect Douglas-fir (*Pseudotsuga menziesii*). In greenhouse studies, unincorporated western bracken litter reduced emergence of all three species but did not influence root and shoot length or dry weight. However, bracken litter incorporated into the soil reduced both shoot length and dry weight of westem thimbleberry seedlings. Allelopathic interactions may explain the relative absence of woody shrubs such as western thimbleberry and salmonberry from sites dominated by western bracken.

93. **STRANG, R.M., and J.V. PARMINTER. 1980. Conifer encroachment on the Chilcotin grasslands of British Columbia. Forestry Chronicle 56:13-18.**

Detailed quantitative examination of a grassland/forest ecotone near Williams Lake, B.C. showed that a combination of fire, grass competition, and subtle microsite determinants of soil moisture availability appear to be the factors influencing tree encroachment most strongly. Historically fire has inhibited tree establishment on the grasslands; between 1759 and 1926, the fire interval approximated 10 years. Presumably because of heavy grazing, no severe fires have burned the area since 1926. Conifer encroachment began in 1931 and virtually ceased in 1972.

94. **TACKLE, D., and D.F. ROY. 1953. Site preparation as related to ground cover density in natural regeneration of ponderosa pine. USDA, California Forest and Range Experiment Station, Berkeley, California. Technical Paper 4. 13 p.**

This study was a preliminary test of securing natural regeneration of ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*P. jeffreyi*) in the eastside pine region of California. Ground scarification was used to simulate fresh logging disturbance on bare ground and to remove vegetation elsewhere. The specific factors studied were (1) germination and survival of seedlings as related to ground cover density on scarified seedbeds and (2) comparative height growth of seedlings on areas of varying ground cover density.

Germination was highest (over 33,000 seeds germinated/ac) on bare seedbeds. As density of ground cover increased, germination declined. Seedbeds with light, medium, and heavy ground cover had 11,420 seedlings, 3,816 seedlings, and 2,914 seedlings per acre, respectively. Seedling survival diminished each year after germination. Percent reductions in survival were about the same for each cover density, but percent loss was more significant for heavy ground cover because far fewer seedlings survived there. Height growth of seedlings also showed pronounced effects of ground cover density. Seedlings on bare areas were not only taller but were much more vigorous in appearance; they had greater needle complement, longer needles, and more robust stems than seedlings on areas with greater cover density.

95. **WAGNER, R.G. 1989. Interspecific competition in young Douglas-fir plantations of the Oregon Coast Range. Ph.D. dissertation, Oregon State University, Corvallis, Oregon. 200 p.**

Improving vegetation management decisions in Pacific Northwest forests requires a better understanding of the interactions between planted conifers and associated vegetation. A practical index of interspecific competition and quantitative models predicting conifer performance from such an index are particularly needed. To meet this need, neighborhood models of interspecific competition were developed for individual trees of Douglas-fir (*Pseudotsuga menziesii*) in the central Oregon Coast Range. A two-phase study was used. In the first phase, preliminary models describing the relation between surrounding nonconiferous woody vegetation and the size of 4- to 9-year-old saplings were developed from a retrospective analysis of two site-preparation experiments. The importance of interspecific competition relative to other factors in the reforestation environment was examined. The second phase tested and refined these models by examining the growth of planted seedlings under a gradient of woody and herbaceous vegetation for 3 years. The influences of abundance, height, distance, azimuth, and spatial arrangement of woody neighbors were evaluated systematically in both phases.

Height and stem-diameter growth of planted Douglas-fir were negatively correlated with all neighborhood measures of interspecific competition. Visual estimates of cover for woody species provided the best measure of neighbor abundance among seven measures tested. Accounting for height of cover relative to the tree improved the models. Height growth of Douglas-fir was influenced primarily by woody neighbors that overtopped the tree, while stem diameter growth was influenced by all neighbors. Woody vegetation was more competitive than herbaceous vegetation.

Competitive influences apparently are one-sided or asymmetric on Douglas-fir height growth, and more two-sided or symmetric on stem diameter growth. Availability of light and soil water in the seedling environment were negatively correlated with neighbor abundance and consistent with the best measures of interspecific competition predicting Douglas-fir growth. Seedling survival was not influenced by competition from woody or herbaceous vegetation.

96. WEAVER, T., and D. PERRY. 1978. **Relationship of cover type to altitude, aspect, and substrate in the Bridger Range, Montana. Northwest Science 52:212-219.**

The relationship of cover type to altitude, aspect and substrate was explored by comparing mapped data for 555 systematic sample points on topographic, geological and vegetation cover type maps. The study area was at 1,678 to 2,593 m elevation in the Bridger Range, Montana. Douglas-fir (*Pseudotsuga menziesii*) forests predominated. Grasses and shrubs were important at low elevations (1,678-1,983 m) and on ESE and SSW slopes, and subalpine fir (*Abies lasiocarpa*) was important above 2,288 m. Lodgepole pine (*Pinus contorta*) occurred at all elevations, but only on NNE and ESE aspects. Douglas-fir cover types were found on limestone and gneiss, grasses on sandstone, and lodgepole pine on interbedded sandstone and shale; subalpine fir did not grow on gneiss. Silvicultural aspects are discussed.

97. WEST, N.E., and W.W. CHILCOTE. 1968. ***Senecio sylvaticus*** **in relation to Douglas-fir clear-cut succession in the Oregon Coast Range. Ecology 49:1101-1107.**

Woodland groundsel (*Senecio sylvaticus*), a northern European adventive, has adapted well to short-term dominance at the beginning of secondary succession on slash-burned clearcuts in the Douglas-fir region. The time/space niche of the species is related to its copious production of small pappus-borne cypselas, low competitive ability, and apparent requirements for the high soil fertility provided by release of minerals directly following slash burning. The high nutrient requirements of this low seral species, compared to succeeding species, are an exception to the generalization that low seral species are usually less demanding of nutrients than are high seral or climax components.

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

Growth of juvenile Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), and whiteleaf manzanita (*Arctostaphylos viscida*) in southwestern Oregon varied with density of codeveloping manzanita and presence of herbaceous cover. The densities of manzanita observed ranged from 0 to 27,000 seedlings per hectare. Xylem pressure potential and stomatal conductance of each species were responsive to competition-induced depletion of soil water. Rates varied among species. The best correlations with growth usually accompanied a 2-year lag between stress and observed response.

Intraspecific competition between individual manzanita seedlings began at age 3 years and became more accentuated, reducing their growth by age 5. The competitive indices used were basal diameter, canopy volume, above-ground biomass, and leaf area. Growth was always least when herbaceous plants were present. Soil moisture depletion was negatively correlated to amount of seedling growth. The community parameters leaf area index, stand biomass, and stand basal area increased most rapidly at the highest densities, suggesting full site occupancy did not occur by age 5.

Six levels of manzanita density were provided by thinning and planting to manipulate biomass, leaf area index, and canopy cover. These parameters were used as interspecific indices of competition for Douglas-fir and ponderosa pine. Competitive influence of shrubs on conifers was slight at age 3 and increased progressively through the fifth year. Stem volume in 1985 was most highly correlated with manzanita canopy cover in 1983. Conifers growing with both manzanita and herbaceous competition had the smallest stem volumes, and those kept herb-free during the first and second years of the study had smaller stem volumes than those that were herb-free during the entire 3 years.

Species showed different strategies in water use. Manzanita maintained high xylem pressure potential and stomatal conductance. Xylem pressure potential was intermediate in Douglas-fir and lowest in ponderosa pine. Douglas-fir and ponderosa pine had similar stomatal conductance. Ponderosa pine may have had access to soil water that the Douglas-fir and manzanita could not exploit.

99. 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.**

Whiteleaf manzanita (*Arctostaphylos viscida*) was established on three sites in 2-year-old mixed stands of Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). Manzanita densities ranged from 0 to 27,000 seedlings/ha. Invading herbs were controlled by spraying all plots except one at each site — the 13,500 manzanita/ha density. Intraspecific manzanita competition reduced individual-shrub basal diameter, leaf area, biomass, and canopy volume by the third year of the study. In contrast, these variables increased at the highest density in the manzanita stand. Stem volume of 5-year-old conifers was reduced in relation to manzanita density, biomass, leaf area index, and canopy cover. The presence of herbaceous vegetation reduced both manzanita and conifer growth by the third year.

100. **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.**

Seeded grasses effectively and economically control successional vegetation in certain Douglas-fir (*Pseudotsuga menziesii*) plantations in northwest Washington, as shown by tree performance measurements and qualitative observations on trials since 1977. Knowledge gained from these trials is being used to prescribe operational-scale grass-seeding treatments for site-prepared areas.

Six to 10 pounds of grass seed per acre provided excellent control of woody vegetation. Survival of planted Douglas-fir in grass-seeded treatments was reduced by an average of 5 to 10% from nearby unseeded areas. The impact of grasses on tree survival and height growth was most apparent on droughty soils. Tree performance and vegetation-control monitoring was continuing on several grass-seeded trials.

101. **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.**

A study of successional trends of lesser vegetation on clearcut and burned areas of old-growth Douglas-fir (*Pseudotsuga menziesii*) indicated great variation in the amount and type of cover between clearcut areas during the first 6 years. The vegetation became more homogeneous with time in both the species present and the amount of cover. The number of species present on the clearcuts increased for about 4 or 5 years. After this time, the number of species remained about the same. Annuals and unidentified species dropped out after the first two growing seasons; unimportant perennials, annuals, and unidentified species disappeared thereafter. Total cover on the area decreased as a result of a decrease in herbaceous vegetation and increase in woody vegetation.

Differences in the amount and type of cover resulting from elevation differences or burning treatment were not evident. Wood groundsel (*Senecio sylvaticus*) and willow-herb (*Epilobium* spp.) were the only species that exhibited a consistent difference between burned and unburned areas. These species had a higher percent cover on burned plots for the first 2 years. South slopes had fewer species present and less total cover. Less cover was contributed by each species on south slopes. The relationship between major species dominating the area on north and south slopes did not differ greatly.

102. YOUNG, J.A., D.W. HEDRICK, and R.F. KENISTON. 1967. **Forest cover and logging — herbage and browse production in the mixed coniferous forest of northeastern Oregon. Journal of Forestry 65:807-813.**

Herbage and browse production of the successional vegetation of the mixed grand fir/Douglas-fir/ponderosa pine/western larch forest were characterized in relation to overstory crown cover. Conifer species and abundance of conifer reproduction also were related to overstory crown cover. In this forest, the highest shrub cover, weight and current annual growth production were associated with moderate overstory crown closure. The negative association between overstory cover and herbage cover or yield was highly significant. Overstory cover accounted for more of the variation in herbage yield than either tree basal area or stems per acre.

Sanitation logging of mixed coniferous forests was both beneficial and detrimental to herbage production. If livestock grazing had been considered in the timber sale and appropriate provisions for disposal of cull logs and slash had been followed, the cutting would have been largely beneficial. Since forage and browse production were stimulated by thinning the overstory canopy, the potential for big game and livestock was increased.

103. YOUNGBERG, C.T. 1966. **Silvicultural benefits from brush. P. 55-59 *In* Proceedings, Society of American Foresters Meeting 1965, Detroit, Michigan. Society of American Foresters, Washington, D.C.**

Many complex interactions take place between crop trees, associated vegetation including weed species and brush, and microorganisms in the soil. Brush and weed species are being eradicated with little or no thought about possible loss of benefits provided by many of the species being eradicated.

In a direct seeding study in the ponderosa pine (*Pinus ponderosa*) zone of central Oregon, it became evident that the brush cover was beneficial to seedlings with respect to moisture and temperature relations. During initial seedling establishment, moisture conditions in the root zone were most favorable under brush. Grass was the only serious competitor for soil moisture. In sapling stands, however, competition for soil moisture became more critical and brush removal increased diameter growth.

Numerous antagonisms occurring in soil may profoundly influence forest stands. The presence of certain species, including species of lesser vegetation, can profoundly affect microbiological processes in the soil. Mineralization of nitrogen is greater where sword-fern (*Polystichum munitum*) litter is mixed with the litter of other species than where the sword-fern litter is the major component.

104. ZEDAKER, S.M. 1981. **Growth and development of young Douglas-fir in relation to intra- and interspecific competition. Ph.D. dissertation, Oregon State University, Corvallis, Oregon. 175 p.**

This thesis explored the relationships between growth of Douglas-fir (*Pseudotsuga menziesii*) seedlings and availability of light and moisture, as influenced by competitor type and density. Twelve 360-m^2 Nelder plots, encompassing a range of 300 to 15,000 cm^2 per plant in 48 spokes, were established in the spring of 1978 in the Oregon Coast Range. Bareroot seedlings (2-0) were planted on three sites representing a cool moist, a warm moist, and a hot dry environment. Irrigation was applied to two of the four plots on each site. Each plot was split into six "pie" sections. Two sections were planted with Douglas-fir alone, two sections had alternating spokes with 1-year-old red alder wildlings, and two sections were planted with Douglas-fir and broadcast-seeded with grass. Observations on soil moisture; plant moisture stress; light attenuation in the seedling canopy; height, diameter and volume growth; and dry matter accumulation were taken at the end of the 1979 and 1980 growing seasons.

Douglas-fir growth was inhibited by competition with red alder (*Alnus rubra*) and grass. Interactions between site and competitor type were significant. Differences in soil moisture depletion and plant moisture stress were indicative of the site-competitor-density interactions. Tree growth was correlated with area per tree, reaching an upper asymptote within the range studied. Moisture did not appear to limit growth in the range of sites studied after first-year irrigation, as long as Douglas-fir had no competitors. Foliage, root, and total biomass per tree were positively correlated with area per tree.

Management of Herbaceous Vegetation

105. ADAMS, S.N. 1975. **Sheep and cattle grazing in forests: a review. Journal of Applied Ecology 12:143-152.**

The world literature on forest grazing by domestic livestock is reviewed. Topics covered include damage to trees, effect on forest soils, vegetation management by grazing, amounts of forage and stocking rates in forests, and management practices favoring forest grazing.

106. ALLAN, G.G., J.W. BEER, and M.J. COUSIN. 1978. **Growth enhancement of a juvenile conifer forest six years after application of a controlled release herbicide. International Pest Control 20:6-13.**

Six treatments were applied to release Douglas-fir (*Pseudotsuga menziesii*) from deciduous brush and herbaceous vegetation in a plantation near Sedro Woolley, Washington. A controlled-release formulation of 2,4-DB chemically bonded to Douglas-fir bark was applied at 0, 200, 500, 1250, and 2000 g to a 2.5-ft^2 area around each tree. This corresponded to application levels of 0, 4.1. 10.2, 25.5, and 41 lb a.e./ac for a planting density of 250 trees/ac and a treatment area of 2.5 ft^2. An equal area around another set of trees was hand-weeded and covered with black plastic.

Six years after treatment, the most effective level of 2,4-DB tested (500 g/tree) increased tree height growth by more than 15% and stemwood volume by 74%, compared with untreated seedlings.

107. ALLAN, G.G., C.S. CHOPRA, and R.M. RUSSELL. 1972. **Selective suppression of weeds and deciduous brush in the presence of conifers. International Pest Control 14:15, 17-20.**

Results of pot experiments on use of controlled-release herbicides to suppress growth of undesirable hardwoods and herbaceous weeds in young plantations or natural stands of conifers were promising. Application of a bark/2,4-DB combination at 10 g/pot severely suppressed growth of red alder (*Alnus rubra*) seedlings but did not affect that of Douglas-fir (*Pseudotsuga menziesii*) seedlings. Douglas-fir seedlings were damaged only slightly by as much as 55 g, but were injured severely by 100 g.

108. ANDARIESE, S.W., and W.W. COVINGTON. 1986. **Changes in understory production for three prescribed burns of different ages in ponderosa pine. Forest Ecology and Management 14:193-203.**

Data on understory production during the 1981 growing season were obtained from pole and mature stands of ponderosa pine (*Pinus ponderosa*) on basalt soil in central Arizona. The three sites had been burned by prescribed fire in autumn 1974, 1976, or 1979. Regression equations were developed to predict plant weight from pine basal area for four common grasses. Remaining herbaceous vegetation was measured by harvesting. During the first 2 years after the burn, herbage production showed no change or a slight decrease. In general, forage and herbage production 5 and 7 years after fires were greater on burned than on unburned plots.

109. **ARNOLD, J.F. 1950. Changes in ponderosa pine bunchgrass ranges in northern Arizona resulting from pine regeneration and grazing. Journal of Forestry 48:118-126.**

On pine-bunchgrass range, (1) grass density declined as pine seedlings became established and developed into saplings; (2) the greater the amount of the 1919 pine canopy, the less was the total herbaceous cover; (3) when protected from grazing, tall bunchgrasses dominated the herbaceous cover under all amounts of tree canopy; under heavy grazing, they were largely replaced by plants more resistant to grazing, except under the heavier tree canopies. Information for judging range condition is presented and other practices for range improvement are suggested.

110. **ARNOLD, J.F. 1953. Effect of heavy selection logging on the herbaceous vegetation in a ponderosa pine forest in northern Arizona. Journal of Forestry 51:101-105.**

Multiple-use management raises the question of the specific effects of logging on the herbaceous forage cover of timbered areas. This paper reports how heavy selection logging affects the herbaceous vegetation of heavily timbered areas in northern Arizona.

Comparison of 224 transects before and 5 years after logging showed that canopy release from heavy selection logging increased the combined area of large and small openings from 43 to 59%. However, canopy release was more than canceled by surface disturbances and by the loss in density of the better perennial bunchgrasses from heavy slash. Loss in bunchgrass density was greatest on logging roads and skid trails, intermediate under the combined effects of canopy increase and heavy slash, and least under increased canopy in the absence of slash. Gain in bunchgrass density was least where canopy release was partially canceled by heavy slash and greatest under canopy release without slash. The results constitute additional evidence against heavy selection logging and support the use of system cuttings.

111. **BALFOUR, P.M. 1989. Effects of forest herbicides on some important wildlife forage species. Forestry Canada and British Columbia Ministry of Forests, Victoria, British Columbia. FRDA Report 020. 58 p.**

This report consolidates information on the effect of forest herbicides on important wildlife forage species by reviewing herbicide trial results from British Columbia, Alberta, Saskatchewan, Washington, Oregon, and Idaho.

Glyphosate severely or very severely damaged sedges (*Carex* spp.) in all treatments except dormant applications. Liquid hexazinone was equally damaging, causing severe to fatal responses in all treatments except the dormant season. The reported effects of glyphosate on grasses were conflicting. Some reports found severe damage; others found "poor control." Rapid recovery may be responsible for the contradictory results. The limited surface area of grasses probably causes variation in efficacy for a leaf-uptake herbicide such as glyphosate. Hexazinone, a "root-uptake" herbicide, is highly damaging to grasses. Efficacy of hexazinone may be related to the depth of the organic layer and to soil moisture. The overwhelming evidence indicates severe damage to grasses, persisting into the second year.

112. **BARBER, H.W., Jr. 1984. Effects of site preparation on survival and moisture stress of interior Douglas-fir seedlings planted in grass. Tree Planters' Notes 35(4):7-10.**

Two-year-old seedlings of Douglas-fir (*Pseudotsuga menziesii*) were planted in April 1982 on grassy plots in Washington. The plots had been spot-treated in September 1981 with atrazine in water (with or without red latex paint) or atrazine in diesel with orange paint. Trees were auger- and hoe-planted; some control plots were thoroughly or minimally scalped. Survivors were counted in August 1982, and predawn moisture stress (PMS) was recorded for some treatments. All atrazine treatments controlled grasses well. PMS was significantly reduced by both thorough and minimal scalping and further reduced by atrazine in water with red paint. Survival was very poor (20%) in auger-planted trees on control plots (no scalping), but was increased to 60% or more by other treatments.

Spot treatment by atrazine in water is recommended to reduce moisture stress and increase survival. The expensive diesel preparation was no more effective, and paint marking did not survive the winter.

113. **BARTOS, D.L., and W.F. MUEGGLER. 1981. Early succession in aspen communities following fire in western Wyoming. Journal of Range Management 34:315-318.**

Clones of aspen (*Populus tremuloides*) in varying degrees of deterioration were burned in northwestern Wyoming in an attempt to regenerate the site. Large numbers of aspen suckers are necessary to perpetuate these stands under current heavy ungulate use. Sucker numbers doubled the second year after burning and by the end of the third year had returned to near preburn levels of 15,000 to 20,000 suckers/ha. This slight increase in sucker numbers probably is insufficient to regenerate the stands under current browsing pressures.

Total understory production declined the first year following fire and then increased to 3,600 kg/ha the second year — almost double preburn conditions. Production decreased the third year to about one-third greater than before burning. Forb and grass production increased and shrubs decreased as a result of burning. Fireweed (*Epilobium angustifolium*) was the largest post-fire contributor to total understory production.

114. **BARTOS, D.L., and W.F. MUEGGLER. 1982. Early succession following clearcutting of aspen communities in northern Utah. Journal of Range Management 35:764-768.**

Changes in aspen (*Populus tremuloides*) reproduction and undergrowth production and composition were recorded over 3 years following clearcutting. Aspen suckers increased from 2,300/ha before cutting to a maximum of 44,000/ha the second post-cut year, dropping to approximately 25,000/ha by the third year. Undergrowth production on the cut units increased from 1,013 kg/ha before cutting to 3,000 kg/ha after three growing seasons; production on the uncut control areas increased from 1,199 to 1,539 kg/ha during this period. The significant increase in undergrowth is attributed to reduction in competition from removal of the aspen overstory. Clearcutting appeared to increase the proportion of shrubs in the undergrowth and decrease the proportion of forbs. A similarity index comparing the cut and uncut areas indicated that the greatest change in species composition occurred the first year after cutting, with a gradual return to precut conditions.

115. **BASILE, J.V., and C.E. JENSEN. 1971. Grazing potential on lodgepole pine clearcuts in Montana. USDA Forest Service, Intermountain Forest and Range Experiment Station, Odgen, Utah. Research Paper INT-98. 11 p.**

Clearcutting of lodgepole pine (*Pinus contorta*) stimulates production of understory vegetation that may provide a grazing resource for livestock and big game for 20 years or more. Peak production of 800 to 1,000 lb/ac occurred about 11 years after clearcutting. Prediction equations were developed to permit gross estimates of potential production and its change with time. Although palatability of the indigenous understory vegetation is low, the large acreages of lodgepole pine that are harvested annually warrant efforts to improve the quantity and quality of forage by reseeding.

116. **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.**

Three combinations of treatments were tested on 2-0 seedlings of Douglas-fir (*Pseudotsuga menziesii*): (1) three ways of packing, (2) four rates of atrazine application (0, 1.66, 3.33, and 5.0 lb/ac), and (3) five lifting dates. All seedlings were planted the day after lifting. Both (2) and (3), as well as the position of planting site on the slope, significantly affected survival; (1) did not affect survival, but significant interactions with (2) and (3) were observed.

117. **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.**

A study was installed on a gentle south slope with a high clay soil near Corvallis, Oregon, to test the suitability of atrazine for use with coniferous seedlings and seed spots. Three rates of atrazine — 5.0, 3.33, and 1.67 lb/ac — were applied in March. Douglas-fir (*Pseudotsuga menziesii*) 2-0 seedlings were planted on all plots on five dates from November to March. Douglas-fir and ponderosa pine (*Pinus ponderosa*) seed spots were randomly placed in each plot, with four spots of each species and five seeds to a spot, on April 30.

At the end of the first growing season, survival was two and five times greater than that obtained on untreated plots for atrazine rates of 1.67 and 3.33 lb/ac, respectively. Growth of both roots and tops clearly was increased in the chemically treated plots.

118. **BLACK, H.C., and B.T. VLADIMIROFF. 1964. Effect of grazing on regeneration of Douglas-fir in southwestern Oregon. P. 69-76 *In* Proceedings, Society of American Foresters Meeting 1963, Boston, Massachusetts. Society of American Foresters, Washington, D.C.**

A cooperative study between the Bureau of Land Management and Oregon State University was begun in 1962. The primary purpose was to determine the long-range effects of controlled grazing by sheep on Douglas-fir (*Pseudotsuga menziesii*) planted on cutover areas typical of foothill land administered by the BLM. Data were gathered on frequency and severity of browsing of Douglas-fir seedlings, the effect of grazing on survival and growth of Douglas-fir, the influence of time of planting on damage, the influence of planting stock type on amount and effects of browsing, depletion of soil moisture by sheep, whether natural and planted seedlings were browsed equally, and whether treatment with TMTD influenced the amount of damage.

At the time of this report, only tentative conclusions could be made because climatic conditions were atypical. The results lend tentative support to the use of controlled grazing as a management procedure, since sheep performed well and did not interfere seriously with establishment of Douglas-fir seedlings.

119. **BLACKMORE, D.G., and W.G. CORNS. 1979. Lodgepole pine and white spruce establishment after glyphosate and fertilizer treatments of grassy cutover forest land. Forestry Chronicle 55:102-105.**

Perennial herbaceous vegetation, mainly marsh reed grass (*Calamagrostis canadensis*), was sprayed with glyphosate 1 day before 1-year-old plugs of lodgepole pine (*Pinus contorta* var. *latifolia*) and white spruce (*Picea glauca*) were planted on cutover forest land north of Edson, Alberta. In June 1976, spraying at 4.5 kg a.i./ha, including spot and strip applications, was compared with unsprayed scalps and controls. At the same time, all treatments were repeated, and a 9-g fertilizer tablet (22-8-22) was added for each seedling. A second experiment, begun in August on the same site, compared scalp, unfertilized control, and glyphosate (4.5 kg a.i./ha) strip treatments, followed by planting of pine seedlings the day after spraying. A third experiment included dosages of 1.1 to 5.6 kg a.i./ha, with planting of pine seedlings in the 4.5 kg/ha glyphosate treatment and the control plots. Application of 2.2 kg/ha in August provided excellent initial vegetation control, as effective as the larger amounts applied, and was superior during the first 12 months to application of 4.5 kg/ha in June. In contrast to results of spring planting, injury and mortality were marked in pine planted in August in glyphosate plots that had been sprayed on the preceding day. Seedlings planted in glyphosate-treated strips 9 months after the August spraying grew more than control plants, but not until the year after they were planted.

120. **BLAKE, J., and D. CROOKER. 1986. Growth response of ponderosa pine following release from grass competition. P. 145-146 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

Established container seedlings of ponderosa pine (*Pinus ponderosa*) were treated with Velpar® 80WP 3 years after planting to control competing grasses on an old-field conversion site. Vegetation control during the first season reduced ground cover by 40%, which was less than the control achieved with normal operational applications in the same area at the same rate. Height growth was not significantly improved the first season after treatment. During the second and third season, height growth increased 88% and 54%, respectively. Stem cross-sectional area at 15 cm also improved by 98%. Survival was unchanged by the treatment. Growth gains continued despite reestablishment of vegetation cover to near pretreatment levels. Investment analysis indicated that, while yield gains can be substantial, the rate of return on this site will be less than desirable unless rotation length is reduced by additional intensive management (thinning and fertilization).

121. **BOYD, R.J. 1982. Chemical site preparation treatments for herbaceous plant communities. P. 49-53. *In* Site Preparation and Fuels Management on Steep Terrain, Spokane, Washington. D. M. Baumgartner, ed. Washington State University, Pullman, Washington.**

Herbaceous plants are often the limiting competitive factor on sites to be reforested with conifers. Even where shrubs are dominant, herbaceous vegetation may influence survival and early performance of conifer regeneration more strongly than does the shrub community. This paper summarizes the advantages and disadvantages of chemical site-preparation treatments and discusses seven commonly used herbicides with respect to mode of action, vegetation controlled, soil residue, and conifer tolerance.

122. **BOYD, R.J. 1986. Conifer performance following weed control site preparation treatments in the Inland Northwest. P. 95-104 *In* Weed Control for Forest Productivity in the Interior West., Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension Service, Pullman, Washington.**

Twenty-four site-preparation trials in the northern Rocky Mountains are described and highlights of tree performance results presented. Most studies tested herbicide and manual or mechanical methods in herbaceous communities. In years of moisture stress, site-preparation treatments enhanced survival, but abundant moisture in the growing season tended to obliterate these effects. Regardless of survival effects, treatments effective in competition control improved subsequent growth of trees grown in treated ground. Both hand and chemical methods improved tree performance, but chemical methods were more cost-effective. Velpar® and Roundup® were the chemicals most often associated with a positive conifer response.

123. **BOYD, R.J., D.L. MILLER, F.A. KIDD, and C.P. RITTER. 1985. Herbicides for forest weed control in the Inland Northwest: a summary of effects on weeds and conifers. USDA Forest Service, Intermountain Research Station, Ogden, Utah. General Technical Report INT-195. 66 p.**

The damaging effects of herbicide treatments on a wide variety of competing species and crop conifers are tabulated. Each item includes weed or tree species, herbicide, application rate, carrier, adjuvants, total mix application rate, application season, plant injury (for up to 4 years), and a reference to the source of the information. Special notes on the use of selected herbicides are also provided. Effects of 16 herbicides on 10 conifers and 34 other species, genera, or plant forms are covered. Herbaceous species include bracken fern (*Pteridium aquilinum*), sword-fern (*Polystichum munitum*), sedges (*Carex* spp.), pinegrass (*Calamagrostis rubescens*), thistle (*Cirsium* spp.), grasses, and forbs.

124. BUERMEYER, K.R. 1982. Seedling performance, soil moisture and available nitrogen associated with chemical site preparation in a lodgepole pine plantation. M.S. thesis, University of Idaho, Moscow, Idaho. 46 p.

Several chemical site-preparation treatments were compared to hand-scalped and control treatments for control of grass and sedge (primarily *Carex geyerii*). Treatments were applied to spots 3 feet in diameter in a plantation of lodgepole pine (*Pinus contorta*) at an elevation of 8,360 feet in southwestern Montana. Hexazinone was applied as a chemical fallow (the growing season prior to planting), as a post-planting treatment, and after the sod was removed by hand-scalping. Glyphosate was applied as a post-planting treatment. Vegetation control, seedling survival, height growth, and condition were recorded and levels of soil nitrate, ammonium, and moisture were sampled for the first two growing seasons.

Nitrate and moisture levels were significantly higher in the hexazinone fallow treatment than in the control or hand-scalp treatments. However, survival was not significantly better than the control and was significantly less than on the hand-scalps, indicating that the treatment was toxic to the seedlings. Height growth was significantly greater on the control than on the hexazinone fallow spots. Although the glyphosate treatment controlled vegetation to some degree and increased soil moisture over the control, it did not significantly improve survival and reduced height growth, even though the seedlings were protected from direct spray. Apparent treatment effects on available nitrogen levels were also addressed.

125. BURCHAM, L.T. 1965. Ponderosa pine management and grazing: a range man's views. P. 65-67 In Proceedings, Society of American Foresters Meeting 1964, Denver, Colorado. Society of American Foresters, Washington, D.C.

In contrast with most other products of forest land, forage production may be greatly increased for several years after the stand is opened by timber harvesting. Utilization of this forage may be an important phase in management of forests and a significant contribution to the local economy. This paper offers some suggestions for grazing management and research on utilization of forage intermittently available after successive harvesting cuts in forests of ponderosa pine (*Pinus ponderosa*) in California.

126. 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, Sacramento, California. University of California, Davis, California.

At the time of the report, browsing damage by black-tailed deer to seedlings of Douglas-fir (*Pseudotsuga menziesii*) in the Pacific Northwest was alleviated principally by animal repellents applied to foliage and by plastic mesh cylinders around individual seedlings. An alternative method, prompt establishment of highly palatable native forbs, reduced summer browsing on planted seedlings to the point that black-tailed deer no longer limited Douglas-fir regeneration.

Establishing native forbs appears to be a sound ecological approach to reforestation problems caused by deer. This approach should have wide utility, because it integrates forest and wildlife management objectives, promoting prompt regeneration of conifers and enhancing wildlife habitat.

127. CASSIDY, H.O. 1937. How cattle may use cut-over ponderosa pine bunchgrass ranges with minimum injury to reproduction. USDA Forest Service, Southwestern Forest and Range Experiment Station, Tucson, Arizona. Research Note 15. 3 p.

Cattle-inflicted injury to reproduction of ponderosa pine (*Pinus ponderosa*) on bunchgrass ranges was studied over 10 years. Thirst was the main factor influencing browsing. Other forms of injury were negligible on reasonably stocked range. Browsing can be curtailed to a level that does not jeopardize regeneration by controlling the factors influencing thirst. Such control can be achieved by reducing stock during the dry summer period or by stocking the full number of cattle but shortening the time the cattle are on the range to one-third of normal.

128. **CHRISTENSEN, M.D., J.A. YOUNG, and R.A. EVANS. 1974. Control of annual grasses and revegetation in ponderosa pine woodlands. Journal of Range Management 27:143-145.**

Application of the herbicide atrazine at 1.12 kg/ha controlled medusahead (*Taeniatherum asperum*) or downy brome (*Bromus tectorum*) enough to permit establishment of perennial wheatgrass (*Agropyron intermedium*) in ponderosa pine (*Pinus ponderosa*) or bitterbrush (*Purshia tridentata*) seedlings transplanted to the plots the following spring. Bitterbrush seedlings established naturally in areas treated with atrazine. Apparently the herbicide created a desirable habitat for seed caching by rodents and reduced competition from annual grasses. Higher rates of atrazine controlled most herbaceous vegetation and resulted in greater growth of ponderosa pine seedlings. Failure to establish perennial grasses resulted in reinvasion by annual grasses.

129. **CLARK, M.B., and A. McLEAN. 1974. Compatibility of grass seeding and coniferous regeneration on clearcuts in the south central interior of British Columbia. British Columbia Forest Service, Victoria, British Columbia. Research Note 63. 10 p.**

The effects of sowing and subsequent grazing of nonrhizomatous species of domestic grasses on establishment, survival and growth of conifers (primarily lodgepole pine [*Pinus contorta*]) were studied in the Kamloops Forest District of interior British Columbia. Determining the effects of grass sowing on reestablishment of native shrubs and forbs was a secondary objective.

Where numbers of cattle and period of grazing were rigidly controlled, damage to conifer seedlings was negligible. Where numbers of cattle were regulated by permit but the period of grazing was too long, damage was extensive. Usually damage was extensive where poor cattle management was evident. With the exception of one area, mortality attributable to animal damage was a minor portion of total losses of coniferous seedlings.

On the average, grass did not affect germination or survival of conifers. In cases where inhibition was apparent, competition from native vegetation was of as much consequence as that from domestic grasses.

130. **CLARK, M.B., and A. McLEAN. 1978. Compatibility of grass seeding and coniferous regeneration of clearcuts in the south central interior of British Columbia. British Columbia Ministry of Forests, Victoria, British Columbia. Research Note 83. 25 p.**

The effects of sowing and subsequent grazing of nonrhizomatous species of domestic grasses on establishment, survival and growth of conifers (primarily lodgepole pine [*Pinus contorta* var. *latifolia*]) in clearcuts were investigated.

Generally, trees and grass are compatible if managers and users of the resources cooperate. The degree of forage utilization and the period when and over which the forage is utilized are the most critical factors in tree/grass compatibility.

Exceptions to many situations can and do occur. Guidelines applicable to specific situations therefore are unreliable, and a holistic approach to the tree/grass compatibility is necessary. One can only assume that certain interactions will occur if specific recommendations are followed.

131. **CLARY, W.P., and P.F. FFOLLIOTT. 1966. Differences in herbage-timber relationships between thinned and unthinned ponderosa pine stands. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-74. 4 p.**

Herbage production was compared under a thinned and an adjacent unthinned stand of ponderosa pine (*Pinus ponderosa*). Herbage production under the thinned stand was significantly greater than under the unthinned stand for given timber basal areas of less than 70 ft^2/ac.

132. **CLARY, W.P., P.F. FFOLLIOTT, and F.R. LARSON. 1987. Factors affecting forage consumption by cattle in Arizona ponderosa pine forests. Journal of Range Management 31:9-10.**

Forage consumption was studied on a summer-use cattle range at elevations of 6600 to 7400 feet. Ponderosa pine (*Pinus ponderosa*) was the main tree species. Forage consumption under rotational grazing was significantly correlated with forage production and, negatively, with ponderosa pine basal area/ac. Consumption was correlated much less with forest crown cover and very little with preference rating of grasses, slope, rockiness of soil, and distance from water. Since the significant variables are those most influenced by timber management, good range management practices can effectively distribute livestock use.

133. **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, British Columbia. Land Management Handbook 9. 88 p.**

This publication summarizes the autecology and distribution of 31 species thought to compete with conifers in British Columbia. Herbaceous species covered include lady-fern (*Athyrium filix-femina*), bluejoint (*Calamagrostis canadensis*), pinegrass (*Calamagrostis rubescens*), fireweed (*Epilobium angustifolium*), sword-fern (*Polystichum munitum*), and bracken fern (*Pteridium aquilinum*). Information is provided for each species on distribution, habitat conditions, shade tolerance, growth habitat, competitive status, benefits to conifers, reproductive characteristics, and response to silvicultural treatments (overstory removal, manual treatments, chemical treatments, mechanical site preparation, and prescribed burning).

134. **COLE, D.M. 1976. Herbicides used for control of lesser vegetation damage young lodgepole pine. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah. Research Note INT-211. 5 p.**

Natural stands of 8- to 10-year-old lodgepole pine (*Pinus contorta*) at 6,400-foot elevation in central Montana were thinned in August 1965. In August 1966, herbicide (5 lb a.i. dalapon, 4.5 lb a.e. 2,4-D, and 4.5 lb a.e. 2,4,5-T/100 gal water) was applied with a hand-held spray boom to understory vegetation until the vegetation dripped. The vegetation consisted mainly of grouse whortleberry (*Vaccinium scoparium*), lupine (*Lupinus* spp.), and elk sedge (*Carex geyeri*). One year after spraying, mortality of young lodgepole pine was 7%; 52% were damaged (nearly half of these seriously). All understory vegetation was killed. After 2 years, mortality was 16%, and sprayed areas were occupied by cheatgrass (*Bromus tectorum*). There was no further mortality after 3 years. Four years after treatment, average 6-year height increment of pine was significantly less on sprayed plots; lupine had become reestablished.

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

Sulfometuron and 2,4-D were applied separately and in combination in two areas in the Oregon Coast Range. The objective was to test the possibility of a broad-spectrum spray that would reduce competition from a variety of shrubs and herbaceous weeds. Mixtures of 2,4-D and sulfometuron gave the best control of the species evaluated in both the herbaceous and shrub weed communities.

136. **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.**

Several herbicide treatments were tested for early-season conifer release on a 2-year-old plantation of Douglas-fir (*Pseudotsuga menziesii*) in coastal Oregon. The area was dominated primarily by herbaceous weeds, including velvetgrass (*Holcus lanatus*) and Australian fireweed (*Erechtites prenanthoides*). Sword-fern (*Polystichum munitum*) and salmonberry (*Rubus spectabilis*) were also present. Plots were sprayed on March 23, 1987, and evaluated in summer 1987. No significant differences were found among treatments for shrubs and ferns. The presence of shrubs and ferns was minimal on all plots, even the control plots. All treatments differed significantly in forb cover from the control plots (29% cover). Plots treated with clopyralid, sulfometuron and 2,4-D ester had less than 4% forb cover. Forb cover on the other treated plots ranged from 6 to 15%. Grass cover was significantly reduced by all but the 2,4-D ester and clopyralid treatments, which had 70 to 78% grass cover, compared to 63% cover for the control plots. The rest of the treated plots had less than 14% grass cover and were not significantly different from each other.

137. **COLE, E.C., and M. NEWTON. 1989. Height growth response in Christmas trees to sulfometuron and other herbicides. Proceedings, Western Society of Weed Science 42:129-135.**

Sulfometuron was applied to Christmas tree plantations of noble fir (*Abies procera*), grand fir (*Abies grandis*), and Douglas-fir (*Pseudotsuga menziesii*) at four rates, pre- and post-budbreak. Atrazine-treated, hexazinone-treated, and untreated control plots also were included. In general, the high rates of sulfometuron, atrazine, and hexazinone treatments were similar in terms of cover reduction. The low rates of sulfometuron generally were not as effective. The early treatments were more effective for grass control, but the later treatments gave better control for some species of forbs, such as thistles. Only grand fir seedlings exhibited no reduction in height growth among the sulfometuron treatments. Growth was reduced in noble fir seedlings at the highest rates of sulfometuron. Established seedlings of Douglas-fir showed a significant trend of reduced growth with increasing rate of application of sulfometuron and with later application. Growth and vigor of seedlings were best in the atrazine and the hexazinone treatments.

138. **COLE, E.C., and M. NEWTON. 1989. Seasonal efficacy comparison of two glyphosate formulations. Proceedings, Western Society of Weed Science 42:136-142.**

The glyphosate formulation traditionally used in forestry has contained 13% surfactant, whereas the formulation to be used in the future contains no surfactant. In order to compare the efficacy of the two formulations, they were applied at different times to four species in the Oregon Coast Range. The site had been logged in 1982 and planted with Douglas-fir (*Pseudotsuga menziesii*) seedlings. Vegetation on the site consisted of red alder (*Alnus rubra*), salmonberry (*Rubus spectabilis*), thimbleberry (*R. parviflorus*), trailing blackberry (*R. ursinus*) and bracken fern (*Pteridium aquilinum*). Applications at two rates were made monthly, June through October.

With the exception of the October applications, all high-rate treatments on bracken fern were significantly different from the untreated controls. Increasing the rate of application significantly reduced cover. No differences between formulations were found.

139. **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.**

Revegetation of burned areas by noncrop species can be rapid, and planted seedlings would have a better environment for growth and survival if vegetation development could be delayed. Four soil-residual herbicides were applied on a burned area in southwestern Oregon on March 21, 1988. The wildfire killed all vegetation and was hot enough to remove the duff layer. Herbicide treatments included atrazine at 9.0 kg a.i./ha; hexazinone at 1.1, 1.7, and 2.2 kg a.i./ha; imazapyr at 0.6 and 0.8 kg a.i./ha; and sulfometuron at 0.11 and 0.21 kg a.i./ha. Seedlings of Douglas-fir (*Pseudotsuga menziesii*) were planted in February. Plots were evaluated in summer 1988 for percent cover of forbs, grasses, and shrubs and for seedling injury.

All herbicide treatments differed significantly from the untreated control but were not significantly different from each other. The imazapyr treatments had the lowest cover, 7 to 9%. The remaining herbicide treatments had 23 to 30% total cover. All treatments, including the untreated control, had significant conifer injury and some mortality. Some injury was related to the hot, dry summer conditions of the site. None of the treatments was significantly different from any other. However, survival was best and injury least on the plots with the least cover (imazapyr).

140. **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.**

Efficacy of different herbicides for controlling herbaceous weeds in newly planted Douglas-fir (*Pseudotsuga menziesii*) was tested on a very productive site in the Oregon Coast Range. Six herbicide treatments were applied pre- and post-budbreak (April or May 1988). Plots were evaluated for percent cover in summer 1988, and conifer injury was rated on a 6-point scale.

Total cover was significantly different from the untreated control on all but one of the herbicide treatments (glyphosate applied at 0.8 kg/ha in April). Control plots averaged 90% total cover, the glyphosate treatment at 0.8 kg/ha in April averaged 57%, and remaining treatments had less than 40%. Total cover was lowest on the atrazine + glyphosate treatment: 12% with the April treatment and 10% with the May treatment. Overall, May treatments reduced total cover significantly better than April treatments. Most of the treatments injured Douglas-fir seedlings to some degree. Severe injury occurred only on plots treated with 2,4-D or glyphosate; some mortality occurred on these plots. Atrazine + 2,4-D in April, sulfometuron, or hexazinone are acceptable choices for control under the conditions of this study.

141. **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 (*Rubus* spp.). Species responses to several herbicides and herbicide combinations are diagrammed by severity of injury. Guidelines provide detailed descriptions of the herbicide spray mixtures and comments on the registration status and efficacy of various treatments.

142. **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 (*Pteridium aquilinum*) and sword-fern (*Polystichum munitum*), as well as various hardwood and shrub species in coastal forests. Species responses to several herbicides and herbicide combinations are diagrammed by severity of injury. Guidelines provide detailed descriptions of the herbicide spray mixtures and comments on the registration status, timing, rates, efficacy, and selectivity of various treatments.

143. **CONWAY, T.M. 1982. Response of understory vegetation to varied lodgepole pine (*Pinus contorta*) spacing intervals in western Montana. M.S. thesis, Montana State University, Bozeman, Montana. 84 p.**

Response of understory vegetation to five spacing intervals of lodgepole pine was determined on five forested sites in Montana and Idaho. The sites represented varied latitudes, elevations, and forest habitat types. Yield and canopy cover of understory vegetation were determined for each spacing interval on each site. Soil temperature and moisture and vegetative crude protein content were also determined with respect to the varied spacings. Yield and canopy cover of understory vegetation on the five sites decreased from wide to narrow tree spacings. Tree canopy cover was correlated with yield, and canopy cover of understory vegetation showed significant negative linear relationships on all sites but one. Although correlations between overstory and understory were significant, tree canopy cover generally accounted for less than 60% of the variation in understory yield and canopy cover on the sites.

The responses of vegetative classes to the varied tree spacings differed; grasses showed the greatest response, followed by forbs and shrubs. Crude protein content of grass, forb, and shrub species did not vary significantly among the spacing intervals. Maximum and minimum soil temperatures differed most under the widest tree spacing and least under the narrowest spacing. Soil moisture did not vary significantly among tree spacings.

Thinning lodgepole pine stands to wide spacing intervals may increase understory vegetation significantly above levels in unthinned or lightly thinned stands. Tree canopy cover may serve as a fairly good predictor of understory vegetation.

144. CROUCH, G.L. 1979. **Atrazine improves survival and growth of ponderosa pine threatened by vegetative competition and pocket gophers. Forest Science 25:99-111.**

Atrazine was applied to 0.004-ha plots of 2-0 ponderosa pine (*Pinus ponderosa*) planted in south-central Oregon. The objectives were to alleviate competition from herbage and remove the food supply of pocket gophers (*Thomomys mazama*), a major cause of reforestation failures. Spring treatments were ineffective, but one or two autumn applications increased pine survival from 25 to over 50%, and height from 146 to over 200 cm after 10 years. Grasses and forbs were reduced the year after autumn treatment, and effects persisted over 10 years. Autumn treatment also reduced gopher mounds 8-fold compared with no treatment or spring treatment. Most pine mortality (although reduced by autumn treatment) was due to gophers, but atrazine also reduced height loss caused by other animals and insects.

145. CROUCH, G.L. 1983. **Effects of commercial clearcutting of aspen on understory vegetation and wildlife habitat values in southwestern Colorado. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-246. 8 p.**

Commercial clearcutting of aspen (*Populus tremuloides*) in southwestern Colorado produced aspen sprouts, but caused relatively few lasting changes in other understory plants 5 years after logging. The most negative impact of logging on wildlife habitat was removal of the overstory, which adversely affected cavity-nesters and other species requiring mature forest.

Forbs were the dominant plant cover in the understory of uncut blocks. Collectively on all plots, the 35 species of forbs contributed 79%, graminoids 13%, and woody species 8% of the total cover. Individual species of understory plants were variously affected by clearcutting. Cover of the two most common grasses, Kentucky bluegrass (*Poa pratensis*) and blue wild rye (*Elymus glaucus*), was diminished by logging and had not recovered in fifth-year blocks. Cover of fringed brome (*Bromus ciliatus*) was greater in older blocks than on the uncut or younger clearcuts. Forbs showed the largest fluctuations among species. Cover of 7 of the 10 most abundant forbs was lower on first-year clearcuts than on uncut blocks. On fifth-year sites, cover of six of these species was no longer different from controls, and cover of two species, licorice-root (*Ligusticum porteri*) and western yarrow (*Achillea lanulosa*), exceeded that on uncut blocks. Among other forbs, only California false hellebore (*Veratrum californicum*) and star-flowered false Solomon's seal (*Smilacina stellata*) were lower in cover on fifth-year blocks than on the controls, whereas sweet-cicely (*Osmorhiza obtusa*) and bluebell (*Mertensia franciscana*) were more abundant 5 years after clearcutting.

146. **CROUCH, G.L. 1986. Survival and growth of ponderosa pine 18 years after planting and atrazine treatment in south-central Oregon. P. 125-128 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

Survival of ponderosa pine (*Pinus ponderosa*) planted in small blocks in April 1966 and treated with atrazine changed little between 1975 and 1983, averaging about 57 and 53% in the respective years. Heights of these trees increased about 10 feet over the period. The original purpose of the study was to control pocket gopher damage by eliminating the food supply. Widespread atrazine treatment and selective poisoning before the initial plantings in the early 1960's and periodically thereafter probably would have resulted in successful regeneration of the study area.

147. **CROUCH, G.L., and E. HAFENSTEIN. 1977. Atrazine promotes ponderosa pine regeneration. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-309. 7 p.**

Atrazine applied by helicopter improved survival of planted ponderosa pine (*Pinus ponderosa*) subjected to competition from herbaceous vegetation and to predation by pocket gophers. Atrazine also improved the seedling establishment environment; seed fall from scattered overstory trees produced 45% stocking and more than 300 trees/ac 7 years after the herbicide was applied.

148. **CURRIE, P.O., C.B. EDMINSTER, and F.W. KNOTT. 1978. Effects of cattle grazing on ponderosa pine regeneration in central Colorado. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-201. 7 p.**

Effects of cattle grazing on regeneration of ponderosa pine (*Pinus ponderosa*) were evaluated on pine-bunchgrass ranges in central Colorado. Good range management practices of light to moderate grazing and adequate water supplies for livestock resulted in negligible damage to natural and artificial regeneration.

149. **DeBYLE, N.V. 1969. Black polyethylene mulch increases survival and growth of a Jeffrey pine plantation. Tree Planters' Notes 19(4):7-11.**

Mulching with a 3 x 3-foot sheet of black plastic material with a 6-inch slit in the middle was beneficial to 2-0 and 3-0 seedlings of Jeffrey pine (*Pinus jeffreyi*) planted in contour trenches on a dry manzanita brush site. Survival and growth were both improved, probably because evaporation from the soil in hot dry weather was prevented.

150. **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.**

This thesis consists of three parts: (1) a field case study involving tree growth, moisture stress, and foliar nitrogen response to sheep-grazed pasture treatments; (2) a shadehouse (potted-plant) study of simulated grazing effects on tree growth and moisture use; and (3) a summary synthesizing results of the field and shadehouse studies and relating both to previous research.

Tree growth in grazed forb-dominated pasture, grazed grass-dominated pasture, and bareground treatments was compared in a 2-year-old agroforestry planting near Roseburg, Oregon. Trees were the KMX pine hybrid (*Pinus attenuata* x *P. radiata*) and Douglas-fir (*Pseudotsuga menziesii*). Height and diameter growth of trees were significantly greater on the bareground treatment. Superior growth of KMX pine, compared with that of Douglas-fir, appeared related to lower xylem moisture stress in summer.

Moisture, rather than nitrogen, appears to limit growth on the site and under the conditions investigated. On similar sites, nitrogen recycled in animal waste is unlikely to induce a tree foliar N response in the establishment phase (0 to 3 years) of tree plantations.

In the semicontrolled shadehouse environment, varied proportions of perennial ryegrass (*Lolium perenne*) and subterranean clover (*Trifolium subterraneum*) were planted in pots with individual KMX pine, Douglas-fir, and *Eucalyptus glaucescens*. Forage in pots was clipped monthly, May until October 1986. To simulate nitrogen return from animal waste, 80% of nitrogen removed was returned as urea after each clipping. A second set of forage treatments was clipped but received no urea. Generally, trees with clover only or with no competing vegetation showed greater growth than trees with grass or mixed clover-grass competition. High grass competition depressed tree growth. Fertilization had no effect on tree growth, although it significantly increased eucalyptus shoot/root ratio.

It was concluded that tree growth in the simulation was limited by moisture. Added urea nitrogen benefited ryegrass growth. Trees competing with the least vegetative biomass produced the greatest growth. Clover was neutral in effect on tree growth. Young tree plantations in grazed western Oregon pastures are unlikely to benefit from animal waste nitrogen. On dry sites, summer moisture stress will limit tree growth and inhibit uptake of animal waste nutrients.

151. **DENHAM, A.C. 1960. Compatibility of grass and trees on eastside Oregon and Washington forests. P. 164-166 *In* Proceedings, Society of American Foresters Meeting 1959, San Francisco, California. Society of American Foresters, Washington, D.C.**

The author argues that forage seeding and timber production are generally compatible and points out that grass seeding is important to retain forest grazing capacity, control soil erosion, and prevent invasion of weeds.

152. **DIMOCK, E.J., II. 1977. Enhancing survival of planted conifers with herbicides on dry sites. Proceedings, Western Society of Weed Science 30:74-75.**

In a trial initiated in 1975, herbicides were sprayed over exposed and protected seedlings of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) shortly after planting. Dalapon at 8 lb/ac + atrazine at 4 lb/ac gave excellent grass control and good to excellent forb control; residual benefit carried into the second growing season. No herbicide damage to conifers occurred, whether seedlings were exposed or protected. After two growing seasons, survival of ponderosa pines sprayed with the mixture was 58%, which was significantly higher than the survival of untreated pines (36%) or pines treated with dalapon alone at 4 lb/ac (32%). Survival of Douglas-fir over the same period did not vary consistently between treatments. In another trial, initiated in 1976, the mixture of dalapon + atrazine gave superior vegetation control to either herbicide used alone. In this trial, dalapon slightly damaged Douglas-fir, but none of the herbicides affected survival of the conifers after one year.

153. **DIMOCK, E.J., II. 1964. Supplemental treatments to aid planted Douglas-fir in dense bracken fern. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-11. 10 p.**

Two-year-old Douglas-fir (*Pseudotsuga menziesii*) were planted in dense bracken (*Pteridium aquilinum*) near Hoquiam, Washington. Treatments at the time of planting were (1) fixing a 2- x 3-foot paper overlay around each plant; (2) cutting and scraping a circle 5 feet in diameter around each plant, followed by periodic bracken cutting each summer; and (3) control, each (a) with and (b) without NP fertilizer application of one 15-g pellet per planting hole. Three years later, neither (1a) nor (1b) showed any benefit, because the paper had been penetrated and had disintegrated. The plots under these two treatments therefore were used to test the effect of spraying 8-foot strips with 50 gal/ac of ACP M-251 at

8 lb/100 gal water. All fronds sprayed were killed; regrowth was much reduced in the following year and moderately reduced in the second year. The Douglas-fir suffered browning and needle fusing, and some died.

After 5 years, neither survival percentage nor height increment was improved by mechanical treatments (1) and (2), while the subsequent spraying in (1) reduced both, and the fertilizer had little effect. Treatment (2) encouraged damage by rabbits and deer. Although survival was still between 88 and 63%, height increment averaged only 17 inches for all treatments. More effective measures are needed.

154. **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.**

In 1977, nine herbicides (asulam, atrazine, bromacil, cyanazine, dalapon, glyphosate, hexazinone, pronamide and terbacil) were applied to sites in Oregon and Washington (1000- to 4000-foot elevation) before or after planting with western white pine (*Pinus monticola*), noble fir (*Abies procera*), Engelmann spruce (*Picea engelmannii*), or Shasta red fir (*Abies magnifica*). The plots were infested with sedge (*Carex* sp.) and beargrass (*Xerophyllum tenax*).

After 3 years, the greatest gains in conifer survival were associated with glyphosate treatment at 2 or 4 lb a.i./ac. On three sites, survival of western white pine was significantly increased by the best glyphosate treatments to 80, 77 or 30%, compared with 40, 34 or 4% on untreated control plots. Glyphosate also increased survival in noble fir and Shasta red fir plots to 56 and 14%, compared with 12 and 0% for control plots. Survival also consistently increased in plots treated with mixtures of atrazine (3-5 lb a.i./ac) and dalapon (6-10 lb/ac). The most successful treatments produced western white pine survival of 62 and 77% (controls, 40 and 34%), Engelmann spruce survival of 46%, and Shasta red fir survival of 14% (controls, 14 and 0%). Sprays applied before planting were usually, but not always, more effective than those applied afterwards.

155. **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 prepared for 2-year-old seedlings of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) by single applications, either before or after planting, of each of seven herbicides and two herbicide combinations. Hexazinone applied at 2.2 kg/ha provided the most effective and lasting herbaceous weed control in both states. A combination of dalapon + atrazine (9.0 + 4.5 kg/ha) was similarly effective. In Washington, each conifer species responded with exponential growth increases over 6 years. Hexazinone treatment increased tree height of ponderosa pine and Douglas-fir by 58 and 70%, stem diameter by 70 and 69%, and stem-volume yield by 387 and 650%, respectively, over untreated checks. Corresponding gains associated with dalapon + atrazine treatment were 73 and 54% in height, 63 and 46% in diameter, and 421 and 349% in yield.

156. **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.**

A mixture of dalapon and atrazine at 8 and 4 lb/ac, respectively, or dalapon or atrazine alone was applied to control perennial grasses and forbs competing with newly planted seedlings of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). In four studies in Oregon in 1975, herbicides were spot-sprayed around individual seedlings. In two studies in Washington and Oregon in 1976, herbicides were broadcast-sprayed. The mixture consistently controlled grass and forbs better than either herbicide alone, reducing grass and forb cover respectively by 80 to 82% and 48 to 58% in the first year. Control persisted for 2 to 4 years. Effects of the different treatments on height growth and survival varied.

157. **DOESCHER, P.S. 1987. Livestock grazing: a silvicultural tool for plantation establishment. Journal of Forestry 85(10):29-37.**

Although livestock grazing in forest plantations is not a new concept, most literature stresses that livestock should be excluded from plantations until terminal leaders of the conifers are beyond reach of browsing animals. However, if grazing is to be a useful tool in conifer establishment, it must be done shortly after planting. For droughty sites in particular, grass or other competing vegetation present during the early years of plantation development may easily reduce survival by 50%.

The author suggests that the following factors be recognized when using grazing animals to suppress competing vegetation. (1) Palatable forage must be available to minimize conifer damage. (2) In areas where moisture is limited during the growing season, vegetation should be grazed before stored soil moisture is depleted. (3) Animal numbers and distribution must be controlled to reduce browsing and trampling damage and ensure uniform vegetation control. (4) Costs of implementing a grazing program must be minimized.

158. **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, Oregon State University Agricultural Experiment Station, Corvallis, Oregon. Special Report 743.**

In southwest Oregon, reforestation has been particularly difficult because of the combined effects of competitive understory vegetation and dry climatic conditions. Past silvicultural prescriptions have strongly emphasized the use of herbicides to control competing vegetation. This report describes initial research activities to assess cattle grazing as a means to promote establishment of conifers. It is assumed that controlled grazing will reduce competing vegetation and increase the availability of soil moisture and nutrients for tree growth.

159. **DYRNESS, C.T. 1973. Early stages of plant succession following logging and burning in the western Cascades of Oregon. Ecology 54:57-69.**

Vegetative changes were documented for 7 years on permanent milacre plots in three clearcut units. Plant cover and composition were observed the year before the old-growth Douglas-fir (*Pseudotsuga menziesii*) forest was logged, after logging but before burning, and during each of five growing seasons following broadcast slash burning. Total plant cover was 15.2, 49.3, and 79.5% in the first, second, and fifth years after slash burning, respectively. Invading herbaceous species dominated from the second through fourth growing seasons after burning, but by the fifth year residual herbaceous species had regained dominance.

Differences in disturbance from logging and burning strongly influenced successional trends. In undisturbed soil areas, residual species such as vine maple (*Acer circinatum*), Oregon oxalis (*Oxalis oregana*), and salal (*Gaultheria shallon*) dominated. Logged but unburned areas supported a wide variety of both residual and invader species. Lightly to severely burned sites were largely occupied by invaders such as snowbrush (*Ceanothus velutinus*), fireweed (*Epilobium angustifolium*), and tall annual willow-herb (*E. paniculatum*).

160. **ECKERT, R.E. 1979. Establishment of pine (*Pinus* spp.) transplants in perennial grass stands with atrazine. Weed Science 27:253-257.**

Atrazine applied at 2.24 to 8.96 kg/ha was evaluated as a preplant treatment for control of perennial grasses in the establishment of Jeffrey pine (*Pinus jeffreyi*) and ponderosa pine (*Pinus ponderosa*) transplants. The most consistent and effective treatments (6.72 and 8.96 kg/ha) reduced grass herbage biomass an average of 72% over 3 years and increased average final survival of transplants from 1% on the control to 66% with treatment. These rates also controlled grass for at least 3 to 4 years after treatment. Stem diameter and top growth tended to be greater on the most effective treatments. High survival and increased growth of transplants on these treatments were attributed to low soil moisture tensions and increased NO_3-N accumulation to depths of 30 cm throughout the summer of the year of planting and subsequent years.

161. EDDLEMAN, L., and A. McLEAN. 1969. **Herbage — its production and use within the coniferous forest. P. 179-196 *in* Coniferous Forests of the Northern Rocky Mountains: Proceedings of the 1968 Symposium. Missoula, Montana. Center for Natural Resources, University of Montana, Missoula, Montana.**

Various aspects and problems of forest grazing in the Pacific Northwest are reviewed. The authors regard the ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) zones as principal multiple-use areas because of their large extent and location. They argue that total productivity of multiple uses usually exceeds that of any single use. They advocate further study of timber/range relationships and make several research recommendations.

162. EDGERTON, P.J. 1971. **The effect of cattle and big game grazing on a ponderosa pine plantation. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-172. 8 p.**

Mixed-conifer stands that have been clearcut, planted with trees, and seeded to grass are a potential source of summer forage for livestock and wildlife. Heights of planted trees in portions of a clearcut that had been ungrazed, grazed only by deer and elk, and grazed by deer, elk, and cattle were compared. After five growing seasons, grazing had neither greatly harmed nor benefited growth and survival of the trees in the plantation.

163. EISSENSTAT, D.M., J.E. MITCHELL, and W.W. POPE. 1982. **Trampling damage by cattle on northern Idaho forest plantations. Journal of Range Management 35:715-716.**

Seedlings of Douglas-fir (*Pseudotsuga menziesii*) planted in April were monitored every 3 weeks from June to October 1978. Only 36% of trees trampled by cattle in the first growing season (about 19% of the seedling population) survived, in contrast to 77% of untrampled trees. Trampling damage was negligible in the second and third growing seasons because of greater protective measures. Browsing damage was low.

164. ERICKSON, J.R., and E.L. MORRIS III. 1986. **Spot application of Velpar L® for grass control in ponderosa pine plantations on Colville tribal lands. P. 127-131. *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

A time study was designed to evaluate costs and production of controlling grass by operational spot application of Velpar L®. Records were kept for worker-hours spent in travel, mixing herbicides, and actual spraying; acres sprayed per worker-day; and total cost per unit, including administration. Under current technology, spot application of herbicides appears to be a viable alternative. The weighted seasonal average cost for spot application of Velpar L® was $23.83/ac. Costs ranged from $20.74 to $45.10/ac.

165. FFOLLIOTT, P.F., W.P. CLARY, and F.R. LARSON. 1977. **Effects of a prescribed fire in an Arizona ponderosa pine forest. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-336. 4 p.**

In October 1964, a prescribed fire burned the forest floor in a ponderosa pine (*Pinus ponderosa*) forest. The objectives included thinning from below, increased seedling establishment, and a temporary reduction of fire hazard.

Herbage production on one area increased from 3 lb/ac before the fire to 40 lb/ac the first year after the fire and continued at that level to year 11. On a second area, herbage production remained at the prefire level of 5 lb/ac the first year after the fire, but increased to 17 lb/ac 11 years after the fire. The herbage composition at both sites changed from primarily mullein (*Verbascum thapsus*), a relatively unpalatable plant, to a mixture of bottlebrush squirreltail (*Sitanion hystrix*), mutton bluegrass (*Poa fendleriana*), showy goldeneye (*Viguiera multiflora*), red-and-yellow-pea (*Lotus wrightii*), and buckbrush (*Ceanothus fendleri*). Generally, the grazing values must be considered negligible on both sites.

166. FFOLLIOTT, P.F., and G.J. GOTFRIED. 1989. **Production and utilization of herbaceous plants in small clearcuts in an Arizona mixed conifer forest. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-494. 5 p.**

Small patch clearcutting has been recommended for managing a variety of resources from southwestern mixed conifer forests. In this study, herbage production and utilization were higher in small clearcuts (0.3 to 1.6 ac) than in adjacent, partially harvested forest stands. Production in the openings ranged from 208 to 355 lb/ac, while production in the harvested forest ranged from 39 to 92 lb/ac. Utilization of herbaceous plants was significantly higher in the clearcuts for two of the three measurement dates. Small patch clearcuts should thus benefit livestock, deer, and elk.

167. 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.**

Efficacy of 16 herbicides in 24 application combinations was evaluated on grasses, sedges, forbs, and shrubs competing with red alder (*Alnus rubra*). Phytotoxicity to red alder stock types, 1-0 bareroot, and 1-0 plug seedlings also was determined. The most effective herbicides for first-year vegetation control were hexazinone, imazapyr, atrazine + dalapon + 2,4-D + triclopyr, sulfometuron, metsulfuron methyl, and glyphosate in combination with 2,4-D or atrazine. Sethoxydim, clopyralid, and pronamide affected this vegetation the least. Red alder plug seedlings appeared to be more sensitive to herbicide treatments than bareroot, but the relative ranking of growth improvement and toxicity were similar. Treatments with the highest survival, vigor, and height included glyphosate + 2,4-D or atrazine, atrazine + dalapon + 2,4-D + triclopyr, and hexazinone (2 lb/ac). The most toxic treatments included sulfometuron, metsulfuron methyl, hexazinone (3 lb/ac) and imazapyr.

168. FISCHER, W.C., and B.D. CLAYTON. 1983. **Fire ecology of Montana forest habitat types east of the Continental Divide. USDA Forest Service, Intermountain Forest and Range Experiment Station, Odgen, Utah. General Technical Report INT-141. 83 p.**

Comprehensive information on fire as an ecological factor for 10 forest habitats east of the Continental Divide in Montana is presented. The relationship of major tree species to fire is described and the responses of undergrowth shrubs, forbs, and grasses to fire are tabulated. Use of fire in each of the forest types is described for stimulating forage and browse production, maintaining grassland for grazing, thinning woody undergrowth, and other purposes.

169. FORESTRY COMMISSION. 1969. **Bracken control with dicamba. Report on Forest Research. Forestry Commission, London. 1968/69 :76-77.**

Trial applications of dicamba to control bracken fern (*Pteridium aquilinum*) are reassessed. Excellent control can be obtained for up to four growing seasons from the date of application at application rates of 4.5 kg/ha on infertile sites. On fertile moist forest sites, however, the bracken may substantially recover by the end of the second season. Application at low volume by mist blower appears to be more practical than application at medium volume by backpack sprayer.

170. FORESTRY COMMISSION. 1970. Bracken control with dicamba. Report of Forest Research. Forestry Commission, London. 1969/70 :82.

Residue from winter applications of dicamba had previously caused some damage to the succeeding crop, so autumn preplanting treatments were tested. Some damage to spring-planted crops still resulted. Grand fir (*Abies grandis*) suffered heavy losses, but European larch (*Larix decidua*), Douglas-fir (*Pseudotsuga menziesii*), and Corsican pine (*Pinus nigra* var. *calabrica*) recovered well after superficial damage. Scotch pine (*Pinus sylvestris*) and Sitka spruce (*Picea sitchensis*) were not affected.

171. FREEMAN, J.B. 1981. Hand application of herbicides for conifer site preparation on the Salmon River Ranger District, Klamath National Forest. P. 67-69 *In* Proceedings, third Forest Vegetation Management Conference, Redding, California. Forest Vegetation Management Conference, Redding, California.

During the four growing seasons previous to the report, the Salmon River Ranger District had hand-applied combinations of atrazine, dalapon, and/or 2,4-D for site preparation on 750 ac burned in a wildfire. Target species included varying densities of heterogeneous stands of grass and shrubs. Grass species consisted primarily of California fescue (*Festuca californica*), needle grass (*Stipa* spp.), orchardgrass (*Dactylis* spp.), brome species (*Bromus* spp.) and cereal rye (*Secale cereale*). Deerbrush (*Ceanothus integerrimus*) was the major target shrub species. The total cost was $175/ac for 302 acres sprayed the spring before the report. Aerially applying the same chemicals on 281 acres cost $98 per acre. Good control was obtained on deerbrush, whiteleaf manzanita (*Arctostaphylos viscida*), and annual and perennial grasses; spotty control on bracken fern (*Pteridium aquilinum*); and spotty to poor control on knobcone pine (*Pinus attenuata*).

172. FULGHAM, K.O. 1986. Plantation grazing in southcentral Oregon. P. 123-130 *In* Proceedings, seventh Forest Vegetation Management Conference, Eureka, California. Forest Vegetation Management Conference, Redding, California.

Data from this study of plantations of ponderosa pine (*Pinus ponderosa*) on the Weyerhaeuser Company Klamath Falls Tree Farm have provided important guidelines for grazing in areas of similar soils and vegetation. Important herbaceous species consisted of western needlegrass (*Stipa occidentalis*), Ross' sedge (*Carex rossii*), bottlebrush squirreltail (*Sitanion hysterix*) and mountain brome (*Bromus marquinatus*).

When grazing management plans are formulated for timbered areas, grazing values of each plantation should be based on (1) species composition, (2) species production and abundance, (3) species quality trends, (4) age of plantation, and (5) location of the plantation in relation to riparian areas. Plant development of early growing forage species and soil moisture content should be key factors in determining the exact calendar date for early season turnout for grazing on plantations. Proper-use factors higher than those associated with grazing climax or stable vegetation should be used. Proper-use factors of 60 to 75% are necessary to reduce herbaceous vegetation that would otherwise compete with trees. Wintering animals on areas where they have access to ponderosa pine needles should be avoided. Cattle eating pine needles become addicted to an alkaloid in the needles and will continue to browse ponderosa pine during the growing season. Ideally, nearly all of the timbered area should be used heavily to benefit the growth of trees, reduce the fire hazard associated with fine fuel abundance, and provide maximum nutrition for the grazing animals.

173. GARRISON, G.A. 1961. Recovery of ponderosa pine range in eastern Oregon and eastern Washington by seventh year after logging. P. 137-139 *In* Proceedings, Society of American Foresters Meeting 1960, Washington, D.C. Society of American Foresters, Washington, D.C.

Observations were made on three areas in the ponderosa pine/pinegrass/elk sedge (*Pinus ponderosa/ Calamagrostis rubescens/Carex geyeri*) type in eastern Oregon and one in the pine/bunchgrass type (*Pinus* *ponderosa/Agropyron inerme-A. spicatum*) of eastern Washington. In Oregon, plant cover increased between the first and second years after logging. Growth of forbs was vigorous, and forbs exceeded their original cover of 3.1% on most areas. Aggressive forbs reached their maximum development of 5.2% in the fourth growing season. By the seventh year, grasses and shrubs approached their original amounts; the less desirable forbs were abundant and disproportionately represented in comparison with their original status. Total understory cover was 11% greater than before logging.

In the pine-bunchgrass type in eastern Washington, the pattern differed somewhat from that in Oregon. By the second year after logging, herbaceous and shrub cover had decreased an additional 14% beyond the 48% loss of the first year. This additional reduction resulted from slash burning. A transient flush of forb growth occurred on burned plots, the effect of a temporary increase in nutrients released by the burning. By the seventh year, cheatgrass (*Bromus tectorum*), a noxious plant, constituted 12% of the understory. The Washington study was much further from recovery than the Oregon areas. Total cover was 16% less than the prelogging cover, forbs were 47% below their original amount, and the lack of the recovery of some grasses was holding cover of perennial grasses 24% below the amount before logging.

174. **GASKIN, R.E., and R.C. KIRKWOOD. 1987. Influence of adjuvants on the activity of asulam and glyphosate in bracken (*Pteridium* spp.). Proceedings of the New Zealand Weed and Pest Control Conference 40:52-55.**

When asulam and glyphosate were applied to two bracken varieties (*Pteridium aquilinum* and *P. esculentum*) at intervals during a growing season, addition of nonionic surfactants generally enhanced absorption and movement of both herbicides in the plants. This was particularly so with fully expanded, mature fronds, where uptake could be improved up to 5- (asulam) and 8- (glyphosate) fold. Herbicide translocation could be similarly increased by factors of 10 and 18, respectively, with the surfactant combinations tested. Glyphosate demonstrated greater uptake and movement in the plant over a wider range of frond development than did asulam.

175. **GORDON, D.T. 1962. Growth response of east side pine poles to removal of low vegetation. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Note 209. 3 p.**

This study, begun in 1955, was designed to elucidate the growth reaction of east-side ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*) to removal of (1) perennial bunchgrass and sedge; (2) broad-leaved plants, principally sagebrush (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*); and (3) both grass and broad-leaved plants. Treatments consisted of (1) control, (2) spraying 2,4-D to kill broad-leaved plants, (3) spraying dalapon to kill grass and sedge, and (4) spraying a mixture of 2,4-D and dalapon. Chemical treatment of the low vegetation caused no visible injury to the trees. Combinations of all low vegetation in this experiment adversely affected growth of the pines, and perennial grass had a greater effect than the broad-leaved plants.

176. **GRAHAM, R.T., A.E. HARVEY, and M.F. JURGENSEN. 1989. Effect of site preparation on survival and growth of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) seedlings. New Forests 3:89-98.**

Survival and growth of Douglas-fir seedlings planted in minimally disturbed, scalped, and bedded soils, both with and without herbicidal control of weeds, were compared at two sites in northern Idaho. Douglas-fir growing for 3 years in bedded soils treated with herbicide were heavier, taller, and had deeper root systems than trees growing in other preparations. Scalping did not improve seedling performance in comparison to minimally disturbed soils. Soils rich in organic matter benefited tree growth. Competing vegetation in raised beds was detrimental to seedling performance.

177. **GRATKOWSKI, H. 1976. Herbicides for grass and forb control in Douglas-fir plantations. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-285. 7 p.**

In March and April 1969, ten herbicides were applied in different concentrations and combinations to Douglas-fir (*Pseudotsuga menziesii*) 6 to 15 inches tall in plantations in southwestern Oregon. Percent reduction in grass and forb cover and damage to the seedlings were estimated visually in June and September 1969 and September 1970. The most effective chemicals for grass control at the end of the first summer were terbacil, atrazine, and dalapon, in that order; terbacil was also effective in the second growing season. Terbacil, granular dichlobenil, and chlorthiamid were the only chemicals that reduced forb cover; of those, only terbacil was effective in the second growing season. Terbacil damaged a few seedlings in the first season, but all were healthy at the end of the second season. Dalapon and granular dichlobenil damaged seedlings but may be useful for site preparation.

178. **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.**

Survival of seedlings of Douglas-fir (*Pseudotsuga menziesii*) increased when atrazine was broadcast-sprayed to control grass in new plantations on three summer-dry sites in southwestern Oregon. Terbacil and 2,4-D were less effective than atrazine. Conifer survival was excellent on four typical coastal sites in or near the fog belt along the southwest Oregon coast.

179. **HALL, F.C. 1975. Range management as a counterpart of forest management. P. 49-63 *In* Range: Multiple Use Management. B. Roche, ed. Washington State University, Pullman, Washington.**

The mixed-conifer/pinegrass (*Calamagrostis rubescens*) plant community of the Blue Mountains in eastern Oregon and southeastern Washington was used to illustrate range management as a counterpart of forest management. The following ecological characteristics of this community type are important for land management. (1) Ponderosa pine (*Pinus ponderosa*) is successional to white fir (*Abies concolor*) and Douglas-fir (*Pseudotsuga menziesii*). (2) Increase in fir changes ground vegetation from high to low forage value. (3) Evaluating range condition and range trend becomes difficult when both livestock use and changing tree cover influence range vegetation.

Predictions of the following were made from these characteristics: (1) reaction of the plant community to thinning stagnated ponderosa pine, (2) high-risk selection of old-growth pine with a fir understory, and (3) reaction of clearcuts when seeded to grass and planted to trees. Characteristics and predictions were used to illustrate how to prescribe treatment of mixed conifer/pinegrass in order to attain a desired forest stand and range condition.

180. **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.**

Farm forestry and grazing were studied in the productive oak woodlands of the Willamette Valley of Oregon. Douglas-fir (*Pseudotsuga menziesii*) could be established under these stands with considerable success. Sheep grazing, when carefully managed, appeared to be compatible with establishment of Douglas-fir. Animal production per acre was influenced by the amount of crown cover of the oak, by the composition of forage species, and by livestock management. Proper timing (season of use) and correct utilization of palatable plants were concluded to be absolutely essential to avoid damage to the Douglas-fir.

181. HANSON, G.F. 1974. Cattle and timber management in the conifer/pinegrass stands of British Columbia. B.S.F. thesis, University of British Columbia, Vancouver, British Columbia. 29 p.

The interactions among trees, cattle, and forage in the Douglas-fir/pinegrass (*Pseudotsuga menziesii/ Calamagrostis rubescens*) and lodgepole pine (*Pinus contorta*)/pinegrass associations of southern British Columbia are discussed. The author suggests that compatibility can be achieved through improved management of timber and cattle.

182. 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.

PSME (Plantation Simulator - Mixed Evergreen) is a computerized growth model for predicting development of Douglas-fir (*Pseudotsuga menziesii*) plantations under specified initial levels of competition from hardwood (tanoak [*Lithocarpus densiflorus*], Pacific madrone [*Arbutus menziesii*], or chinkapin [*Castanopsis chrysophylla*]) and from herb/shrub vegetation in southwestern Oregon. It uses values for cover of competing vegetation and average size of Douglas-fir seedlings at stand-age 3 years, or for preharvest stand information on hardwood basal area and density, to provide tabular and graphical ouput of the development of the Douglas-fir hardwood and herb + shrub components through stand-age 10 years. It also predicts frequency distributions of Douglas-fir height and stem diameter at 10 years. 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 manual provides software for PSME, information on model installation and application, and techniques for collecting input data.

183. HARRIS, G.R., and W.W. COVINGTON. 1983. The effect of a prescribed fire on nutrient concentration and standing crop of understory vegetation in ponderosa pine. Canadian Journal of Forest Research 13:501-507.

Understory vegetation from sawtimber, pole, and sapling strata on basalt soils in Arizona was sampled for biomass and nutrient concentrations in summer 1977, following a prescribed fire in autumn. Nutrient concentrations were generally, but not always, significantly higher on burned than unburned plots, with striking differences among overstory strata. Potassium levels responded most consistently, while nitrogen levels increased the most. The greatest increases in nutrients were in the sawtimber stratum, where nitrogen concentration of Arizona fescue (*Festuca arizonica*) and the miscellaneous grasses category was at times twice as high on the burned sites. Differences in understory biomass were most obvious in September, when values in both pole and sapling strata were twice as high on burned plots as controls. These production and nutrient responses varied depending on species, overstory type, and season. In general, this prescribed fire appears to have increased nutrient concentrations, thus improving forage quality for both livestock and wildlife.

184. HEDRICK, D.W. 1966. Forest grazing in northeastern Oregon. Oregon State University Agricultural Experiment Station, Corvallis, Oregon. Special Report 215:13-17.

Research conducted from 1955 to 1966 at the Eastern Oregon Experiment Station is summarized. The author concludes that there is a high potential for both forage and timber production on ash-covered sites supporting mixed coniferous stands, but emphasizes that close collaboration of forest and range managers in planning improvement programs is required to realize this potential.

185. HEDRICK, D.W. 1975. Grazing mixed conifer forest clearcuts in northeastern Oregon. Rangeman's Journal 2:6-9.

Experimental work on forest grazing conducted by researchers at Oregon State University is summarized. The author proposes livestock management practices for minimizing damage to coniferous regeneration and sustaining forage productivity.

186. **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 1952 and 1953, 2-0 Douglas-fir seedlings were planted in 3 situations: (1) clearcut, (2) thinned oak, and (3) fully stocked oak. From 1955 through 1960, yearling ewes were grazed 3 or 4 weeks each spring on half of each of the three original plots. Animals were brought in each spring when there was adequate herbaceous forage and removed when they ceased to gain weight. Soil moisture was measured through the growing season on all plots.

Seedlings of Douglas-fir (*Pseudotsuga menziesii*) planted in an Oregon white oak (*Quercus garryana*) foothill area grew faster in grazed than in ungrazed plots. After 3 years of spring grazing, Douglas-fir tree height growth became significantly greater on the grazed plots, and continued so during 4 more years of grazing, and until the third year after grazing was terminated. More abundant soil moisture correlated well with removal of much palatable herbage by sheep. Seedling growth was most rapid on the clearcut plot, fair on the thinned plot, and slowest on the plot with the full oak canopy. Ten years after grazing started, Douglas-fir tree heights averaged 25 inches greater (27%) on the grazed than on the ungrazed plots.

187. **HEERWAGEN, A. 1955. The effect of grazing use upon ponderosa pine reproduction in the Rocky Mountain area. P. 206-207 *In* Proceedings, Society of American Foresters Meeting 1954, Milwaukee, Wisconsin. Society of American Foresters, Washington, D.C.**

The author argues from past research and field observation that timber and grazing uses can be compatible in ponderosa pine (*Pinus ponderosa*) forests of the central and southern Rocky Mountains. Moderate grazing, coupled with provisions for preventing livestock concentration, not only results in negligible damage to young pine reproduction, but is of substantial silvicultural benefit in reducing herbaceous competition and fire hazard. Excessive grazing not only is detrimental to the establishment of pine reproduction, but also seriously reduces forage production and results in erosion, site deterioration, and depletion of watershed values.

188. **HEIDMANN, L.J. 1968. Herbicides for preparing ponderosa pine planting sites in the Southwest. Down to Earth 24(1):18-20.**

Spring drought combined with competing vegetation can effectively prevent establishment of ponderosa pine (*Pinus ponderosa*) seedlings in the Southwest. In northern Arizona, the most serious competition is from perennial grasses, primarily Arizona fescue (*Festuca arizonica*). They can utilize most of the available soil moisture at the expense of pine seedlings and are also responsible for reduced growth of established trees.

Several herbicides (dalapon, amitrole, simazine, ammonium thiocyanate) were tested. At a rate of 5 lbs of dalapon/ac, 80% of the grass died in 1961 and 94% in 1962. All applications of dalapon were cheaper than simazine at 10 lb/ac, which killed 92% of the grass in 1961.

189. **HEIDMANN, L.J. 1969. Use of herbicides for planting site preparations in the Southwest. Journal of Forestry 67:506-509.**

Competing vegetation, especially perennial grass, takes soil moisture that is needed to reproduce ponderosa pine (*Pinus ponderosa*) in the Southwest. Soil moisture trends were followed on herbicide-sprayed, scalped, and untreated plots near Flagstaff, Arizona, in 1961 and 1962. The study area was almost completely occupied by Arizona fescue (*Festuca arizonica*) and mountain muhly (*Muhlenbergia montana*). Soil moisture was significantly higher on herbicide-sprayed plots, particularly for the 0- to 8-inch zone, than on the scalped or untreated plots. The differences were greater during an abnormally dry season than during a normal one.

190. HESS, J.P. 1983. **Forestland grazing policy and practices on private timberlands in central Washington. P. 101-103 *In* Forestland Grazing: Proceedings of a Symposium, Spokane, Washington. B. F. Roche, Jr. and D. M. Baumgartner, eds. Washington State University, Pullman, Washington.**

Livestock grazing on Boise Cascade timberlands is described. The author concludes that the investment in plantation or natural regeneration effort is too great to allow grazing damage to occur at any stage of reproduction. Nevertheless, it is noted that coordinated resource planning has aided in achieving proper livestock grazing on private timberland.

191. HEUSCHKEL, D.G. 1956. **Tests of some chemical herbicides in controlling brush, weed trees, and grasses on the McDonald Forest. M.S. thesis, Oregon State University, Corvallis, Oregon. 73 p.**

This thesis summarizes herbicidal experiments established by the Oregon State College School of Forestry to test a variety of herbicidal products on 37 plant species common in the school forest. The report was essentially preliminary, since most of the conclusions are based on the results of only one growing season.

The grasses tested were best controlled by a mixture of brushkiller and Chloro IPC. Seedlings of Douglas-fir (*Pseudotsuga menziesii*) were planted several months after the grasses had been sprayed. In all cases, seedling mortality was higher on sprayed than on unsprayed plots, so further research would be necessary to find a new chemical or a concentration of the above chemicals that will control the grasses but be relatively harmless to the seedlings.

192. HILL, R.R. 1917. **Effects of grazing upon western yellow pine reproduction in the national forests of Arizona and New Mexico. USDA, Washington, D.C. Bulletin 580. 27 p.**

This study was done to determine the character and extent of damage caused by livestock grazing on young growth of western yellow pine (*Pinus ponderosa*) in the Southwest and to find the best way to minimize such damage while permitting proper utilization of the range.

Over 3 years, 1,493 of 8,945 trees of a size subject to grazing (16.7%) were severely damaged each year, and 1,442 (16.1%) were moderately damaged. Seedlings were the most seriously damaged; damage gradually decreased with an increase in tree size. The greatest damage occured during the latter half of June and the first part of July, when the effects of the spring dry period are most pronounced. On overgrazed areas, all classes of stock are apt to damage small trees severely. The suitability of the forage to the class of stock using a range has an important influence on the amount of damage to timber reproduction.

The effect of grazing on height growth was marked. Severely injured trees grew only from one-half to one-third as fast as uninjured trees. However, permanent effects of grazing injuries on development of trees were not serious, provided the damaged trees had a chance to recuperate. If grazing is unrestricted, about 15% of the total stand is likely to be killed during the period required for reproduction to become established.

193. JOSTEN, G.J. 1981. **Control of pinegrass by herbicide as a site preparation technique in two western Montana clearcuts. M.S. thesis, University of Montana, Missoula, Montana. 77 p.**

Pinegrass (*Calamagrostis rubescens*) is a rhizomatous forest grass that responds prolifically to surface scarification and burning. Herbicides were applied to two western Montana clearcuts to study their effectiveness as an alternative site-preparation technique for controlling pinegrass. Seven combinations and rates of glyphosate, hexazinone, atrazine, and dalapon were applied at the Blue Mountain site. Two more herbicide combinations plus a scalp were tested at the White Stallion site. Applications were made in June 1979, September 1979, and May 1980 at Blue Mountain, and June 1980 at White Stallion. Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) were planted before and after application.

Glyphosate alone successfully controlled pinegrass if applied in June; hexazinone was most successful in the fall or spring. Dalapon was most successful in the fall. Atrazine alone did not successfully control pinegrass at any application time. Dalapon + atrazine was most successful when applied in the fall or spring; however, other chemical combinations were generally no more successful than one of the chemicals applied alone. Generally, seedling survival improved and moisture stress was less if seedlings were planted after or one year before herbicide applications. Seedlings at White Stallion that were sheltered from glyphosate, applied alone or in combination, had better survival and lower moisture stress than those exposed to the spray. Seedling survival on scalped plots was high; however, competing vegetation quickly reoccupied the plots, and plant moisture stress was generally high relative to control seedlings.

194. 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, Portland, Oregon. Technology Transfer Bulletin. 15 p.**

A court ruling forbidding the use of herbicides on BLM lands in western Oregon made it necessary to investigate alternative vegetation control methods. This study assesses the effects over 5 years of using grass-legume mixtures as a vegetation management tool in three clearcuts in the Oregon Coast Range. Study sites were 1 to 2 ac. Half of each site was seeded and fertilized; the other half was not seeded. Seedlings of Douglas-fir (*Pseudotsuga menziesii*), salmonberry (*Rubus spectabilis*), thimbleberry (*Rubus parviflorus*), and red alder (*Alnus rubra*) were permanently marked and measured.

Seeding with a mixture of grasses and legumes appeared to reduce the occurrence and cover of salmonberry and thimbleberry substantially, especially during the first 3 years of the stand. Seeding generally reduced height growth of salmonberry, thimbleberry, and Douglas-fir seedlings. Grass cover of more than 30% was required to reduce cover of salmonberry effectively. Survival of Douglas-fir seedlings was not significantly influenced by seeding. For the first 2 years, animal damage was not influenced by seeding, but large numbers of big game animals potentially could be attracted into seeded areas, which could result in a high degree of seedling damage from browsing. Quality of mountain beaver habitat did not appear to be reduced by seeding, since sword-fern (*Polystichum munitum*) cover was not consistently less in the seeded areas. After 5 years, no damage from meadow mice had occurred to Douglas-fir seedlings in the seeded areas. Seeding seemed to reduce surface soil erosion effectively, and proliferation of grass roots probably increased the amount of organic matter incorporated into the surface soil.

195. KELPSAS, B.R., and F.W. PFUND. 1990. **Western red cedar response to spring grass control herbicides. Proceedings, Western Society of Weed Science 43:45.**

Chemicals for control of herbaceous weeds have not been widely tested over western red cedar (*Thuja plicata*). Two field trials, one over newly planted cedar and the other over established seedlings, were instigated in 1989. Several herbicides damaged red cedar. Established seedlings were severely damaged by hexazinone (60% crown kill), and less so by 2,4-D + atrazine (25% crown kill). Atrazine alone injured crowns the least (<5%), with sulfometuron and all glyphosate treatments near 10% injury. Herb control following treatment also varied by herbicide. Herb cover remaining around hexazinone-treated seedlings was the lowest of all treatments (less than 10%), followed by atrazine + glyphosate (12%) and sulfometuron (14%).

Although hexazinone and sulfometuron provide better weed control, they can be damaging over red cedar. Atrazine alone may be the best treatment for both avoiding injury and controlling herbaceous vegetation.

196. **KINGERY, J.L., and R.T. GRAHAM. 1987. Cattle grazing and forest animal damage interaction. P. 119-132 *In* Animal Damage Management in Pacific Northwest Forests, Spokane, Washington. D. M. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick, and D. W. Breuer, eds. Washington State University, Pullman, Washington.**

Direct damage to tree seedlings by livestock on three study areas in northern Idaho was less than expected, but grazing influenced the role of other causes of damage. Where grazing was light and ground cover was high, damage to tree seedlings by above-ground rodents was highest. Percent damage and mortality resulting from deer and elk grazing were similar to those caused by livestock, except in steep terrain. Contrary to some earlier research, this study found poorest tree seedling performance on the more favorable habitat types. Temperature and moisture conditions that favor tree establishment also favor those factors that most contribute to damage to and mortality of tree seedlings.

197. **KINGERY, J.L., R.T. GRAHAM, and J.S. WHITE. 1987. Damage to first-year conifers under three livestock grazing intensities in Idaho. USDA Forest Service, Intermountain Research Station, Ogden, Utah. Research Paper INT-376. 8 p.**

Three study areas with high potential for both forage and timber production were planted with 2-0 seedlings of ponderosa pine (*Pinus ponderosa*). Douglas-fir (*Pseudotsuga menziesii*) was coplanted in one area, and western white pine (*Pinus monticola*) was coplanted in two areas. Within each area, uniform sites were located to represent light, medium and heavy intensities of livestock grazing. Frequent observations were made after planting to define and quantify causes of seedling damage and mortality. Intensity of livestock use and livestock management practices appeared to influence damage associated with livestock, big game, pocket gophers, other rodents, and nonanimal factors. When all sites were considered together, livestock caused little direct damage. Rotation grazing appeared to reduce damage and mortality to seedlings. Pocket gophers caused most damage; the greatest damage occurred on sites with the least livestock grazing.

198. **KORPELA, E.J. 1983. Forage quantity and quality within managed ponderosa pine plantations in southcentral Oregon. M.S. thesis, Humboldt State University, Arcata, California. 150 p.**

The quantity and nutritional quality of forage produced in managed plantations of ponderosa pine (*Pinus ponderosa*) in southcentral Oregon were investigated. Forage production was modeled as a function of plantation age class for 1- through 8-year-old plantations. Regression models were developed for both total dry weight forage and dry weight grass production. Forage production rapidly increased with plantation age and reached maximum values at 4 years of age. Peak total forage production was 578 lb/ac; peak grass production was 445 lb/ac. Since this forage represents a grazable resource, stocking rate guidelines were developed for the plantations. In addition, the models were graphically extrapolated to show how long significant quantities of forage for grazing would be produced within the plantations.

Seasonal trends in forage quality were described for five major forage species in the plantations. Trends in moisture content, crude protein, *in vitro* dry-matter digestibility, and digestible energy were described for Ross' sedge (*Carex rossii*), mountain brome (*Bromus marginatus*), Kentucky bluegrass (*Poa pratensis*), bottlebrush squirreltail (*Sitanion hystrix*), and western needlegrass (*Stipa occidentalis*). Forage quality was generally highest early in the season and declined with advancing plant maturity. Ross' sedge, however, retained higher levels of moisture, crude protein, digestibility, and digestible energy later into the season than did the four grasses sampled. The trends in crude protein and digestible energy were also related to animal needs. Crude protein levels fell below animal requirements earlier in the season than did digestible energy. The implications for plantation grazing suggested by the trends in nutritional quality of the forage produced within the plantations were also discussed.

199. **KOSCO, B.H. 1980. Combining forage and timber production in young-growth mixed conifer forest range. Ph.D. thesis, University of California, Berkeley, California. 124 p.**

The mixed-conifer forest of California provides an important source of both herbaceous and browse forages, which are major components of livestock diets on the range. Optimal resource use requires understanding the interactions between livestock grazing and timber production, watershed, wildlife, and recreation.

The study was carried out on the west slope of the Sierra Nevada at 1,300 to 1,500 m elevation. Cattle have grazed the region since the 1850's. Species composition, production, and utilization in meadows were determined. Primrose monkey-flower (*Mimulus primuloides*) and rushes (*Juncus* spp.) were the most common of the more than 20 species encountered. Grasses provided only a small amount of the meadow forage. Herbaceous standing crop averaged 2,880 kg/ha, and utilization remained stable at 60% during the study (between 1977 and 1979).

Cattle did not damage tree regeneration. Rather, deer caused most of the browsing damage to conifer seedlings, especially white fir (*Abies concolor*). Trampling damage was negligible. In addition, cattle and deer significantly reduced brush cover on the clearcuts over the ungrazed control plots by grazing most immature brush species.

The historical pattern of use in a given timber management compartment appears to be the most important factor affecting understory cover. Overstory canopy cover, slope, aspect, and time since the last harvest are also important. Basic ecological research on responses of individual understory species to disturbance, shade, and fire need to be examined further in order to optimize forest management.

200. **KOSCO, B.H., and J.W. BARTOLOME. 1983. Effects of cattle and deer on regenerating mixed conifer clearcuts. Journal of Range Management 36:265-268.**

In a study near Georgetown, California, cattle grazed the study area from June 1 until September 20 each year. Deer in the study area are primarily migratory, passing through in March and April and again in October and November each year. The results of treatments on two clearcuts indicate that cattle do not harm tree regeneration. Browsing on trees occurred, but the number of trees browsed by cattle and deer was not significantly higher than by cattle alone. Seedlings of white fir (*Abies concolor*) were browsed the most heavily. No trampling damage occurred. Browsing made no difference in overall tree seedling height or basal diameter between treatments. Brush cover was significantly reduced on grazed treatments on both clearcuts. The reduction in brush cover had no effect on tree seedling heights or basal diameters. Proper cattle grazing did not seem to harm tree regeneration on young mixed conifer plantations. Furthermore, cattle grazing may be used as vegetation management to reduce brush on these clearcuts.

201. **KRUEGER, W.C. 1983. Cattle grazing in managed forests. P. 29-41 *In* Forestland Grazing: Proceedings of a Symposium, Spokane, Washington. B. F. Roche, Jr. and D. M. Baumgartner, eds. Washington State University, Pullman, Washington.**

This paper summarizes research since 1971 on cattle grazing on forested rangelands in northeastern Oregon and on 20 years of grazing on a forest plantation.

The riparian zones studied in the forest, which were utilized at about 75% of current year's growth on herbaceous vegetation, were vegetatively stable. Plant community structure over the long term was most influenced by logging in the mixed coniferous forest. Big game grazing was of secondary importance, and cattle grazing had the least impact on floristic structure. In a more open Douglas-fir/ponderosa pine (*Pseudotsuga menziesii*/*Pinus ponderosa*) type, cattle influenced the structure of herbaceous vegetation, whereas big game influenced the structure of the shrub components.

In the plantation, succession of vegetation proceeded from an early bull thistle (*Cirsium vulgare*) phase to a dominance of seeded grasses or, in unseeded areas, to dominance of Kentucky bluegrass (*Poa pratensis*) and elk sedge (*Carex geyeri*). Seeded forages did move to unseeded areas, but did not dominate the unseeded areas 18 years after seeding. At the end of the second decade, shrubs had the major influence and reduced forage by about 50%. In addition, the canopy closure 18 years after seeding reduced overall yield by about 45%. Seeding forages in the clearcut had no influence on survival or height of planted conifers. Height growth of conifers was maximum on the pasture grazed by cattle and big game.

202. **KRUEGER, W.C. 1986. Grazing for forest weed control. P. 83-88 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

Research throughout the world clearly indicates that grazing has utility for weed control when the needs of both the forest plantation and grazing livestock are met. Operational grazing programs on the national forests and private timber company plantations show that grazing is practical when implemented on a large scale. The world literature is reviewed and operational plantation grazing programs on the Siuslaw National Forest, on Weyerhaeuser Company lands in southern Oregon, and on the Oregon State University Hall Ranch in eastern Oregon are discussed in detail.

203. **KRUEGER, W.C., and A.H. WINWARD. 1974. Influence of cattle and big game grazing on understory structure of a Douglas-fir - ponderosa pine - Kentucky bluegrass community. Journal of Range Management 27:450-453.**

A Douglas-fir/ponderosa pine/Kentucky bluegrass (*Pseudotsuga menziesii/Pinus ponderosa/Poa pratensis*) community was studied 14 years after grazing by cattle and big game, by big game, or by neither cattle nor big game. Heavy season-long use by cattle and big game resulted in apparent retrogression. The herbaceous component of the community was substantially changed by cattle and big game grazing, but not by big game grazing alone.

204. **KRUEGER, W.C., and A.H. WINWARD. 1976. Effects of grazing and selective logging on a mixed coniferous forest. Proceedings of the Oregon Academy of Science 1976:27-35.**

No significant changes in community structure were attributable exclusively to heavy cattle grazing, although grazing by big game or by cattle and big game together did alter secondary succession. Residual effects of logging had more total influence on community structure than grazing.

205. **LEININGER, W.C. 1984. Silvicultural impacts of sheep grazing in Oregon's coast range. Ph.D. dissertation, Oregon State University, Corvallis, Oregon. 211 p.**

In field trials in 1980 through 1982, herded sheep were used to suppress brush in plantations of Douglas-fir (*Pseudotsuga menziesii*). Sheep browsing of Douglas-fir was highest in May after bud opening; over 2 years of grazing, the sheep ate an average of 28% of the current year's growth. Browsing of growing points ceased when seedling height exceeded the reach of the sheep. Less than 3% of the trees were trampled down. Two-year-old Douglas-fir showed growth damage by sheep, but 4- to 6-year-old trees showed increased growth, possibly as a result of increased nitrogen from sheep excreta. Douglas-fir represented 3% of the annual diet of the sheep, which was composed of 40% graminoids and 40% forbs in young plantations and 70% graminoids and 16% forbs in older plantations. Weight gain of sheep followed seasonal trends typical of sheep grazing nonirrigated hill pasture in western Oregon.

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

The seasonal diets of herded sheep grazing cutover forests of Douglas-fir (*Pseudotsuga menziesii*) in the Coast Range of Oregon were studied during 1981 and 1982. Both 4- to 6-year-old unseeded and 2-year-old grass-seeded plantations were included. Sheep grazing was monitored in spring, summer and late summer. Available forage ranged from 764 to 2,459 kg/ha. Vegetational composition of sheep diets varied by year, season, and plantation age class. Over the 2 years of grazing, graminoids and forbs were nearly equal in sheep diets in older plantations, averaging about 40% each. In contrast, diets of sheep in young grass-seeded plantations averaged 70% graminoids and only 16% forbs. Ferns were a minor component (2%) of sheep diets in both plantation age classes. Browse averaged 15% and 12% of sheep diets in old and young plantations, respectively. Douglas-fir was most palatable to sheep in spring soon after bud break. It was generally avoided, however, and never comprised more than 3% of sheep diets.

Sheep can be most effectively used for biological control of unwanted brush species during summer and late summer, when differences in relative preference indices for target brush species and Douglas-fir are greatest.

207. LEWIS, B.P. 1967. Forb production and utilization in western Montana clearcuts. M.S. thesis, University of Montana, Missoula, Montana. 101 p.

The objectives of this study were to describe the vegetation on clearcuts within different forest zones, to determine the use cattle make of these cutover areas, and to determine the preference of cattle for certain species and groups of species on the cutover areas.

Fourteen clearcuts were studied: 4 in the spruce/fir (*Picea engelmannii/Abies lasiocarpa*) zone and 10 in the Douglas-fir/larch (*Pseudotsuga menziesii/Larix occidentalis*) zone.

Clearcutting in the Douglas-fir/larch zone was accompanied by an increase in total vegetative cover over that found in the forest understory, while clearcutting in the spruce/fir zone was accompanied by a decrease in total cover on the cutover areas. Grasses and grass-like plants were more abundant on the cutover areas than in the forest understory. Cover of forbs and shrubs remained the same or decreased on the cutover areas in both forest zones. Burning decreased total canopy coverage and increased poor forage species; however, these undesirable effects were probably offset by the favorable effect of reduced slash on cattle distribution. Cattle made little use of the cutover areas. Grasses and grass-like plants were the most important forage species. Of these, pinegrass (*Calamagrostis rubescens*) and elk sedge (*Carex geyeri*) provided most of the forage on the cutover areas.

208. LINDSTRAND, L. 1983. Chemical and mechanical grass control. P. 47-55 *In* Proceedings, fourth Forest Vegetation Management Conference, Eureka, California. Forest Vegetation Management Conference, Redding, California.

Weed control and tolerance of conifer seedlings were tested in field trials of soil-active weed-control compounds (atrazine, simazine, hexazinone, pronamide, norflurazon, and fluridone). The two major weed species in the trial area were California needlegrass (*Stipa californica*) and squirreltail (*Sitanion hystrix*), both perennial grasses. Tree seedlings tested were 2-0 bareroot Jeffrey pine (*Pinus jeffreyi*) and 1-0 container white fir (*Abies concolor*). The objectives were (1) to examine conifer tolerance to these compounds under both preplant and postplant conditions on disked and undisked ground and (2) to see how much control could be expected at two different times of application. The fall application on disked plots gave best grass control, ranging from 70% with norflurazon to 100% with hexazinone; the control plot had 43%.

209. LOEWENSTEIN, H., and F.H. PITKIN. 1970. Ponderosa pine transplants aided by black plastic mulch in Idaho plantation. Tree Planters' Notes 21(4):23-24.

Seedlings (1-1) of ponderosa pine (*Pinus ponderosa*) were planted on an old-field site in spring 1965 and 1966, at 3-foot spacing in rows 7 feet apart. Black plastic mulch greatly increased height growth after four or five growing seasons in comparison to clear cultivation, herbicide (simazine) treatment, or no treatment. Over this period, the black plastic remained virtually intact and prevented weed encroachment, which became severe on the other plots. White plastic mulch, included in one test in the hope that it would increase photosynthesis, disintegrated rapidly and did not enhance photosynthesis detectably.

210. LOTAN, J.E. 1986. Silvicultural management of competing vegetation. P. 9-16 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.

Because of concerns about side effects of chemicals and excessive disturbance of the harvested area, silviculturalists should use integrated vegetation management and silvicultural strategies to curtail vegetation that competes excessively with tree seedlings. Characteristics of competing vegetation are presented and examples are given for using integrated vegetation management to manage problem species of the Intermountain and Northern Rocky Mountain regions.

An example is given for the treatment of pinegrass (*Calamagrostis rubescens*) and elk sedge (*Carex geyeri*). Both species tolerate shade well, persist throughout all successional stages, and rapidly colonize disturbed areas. The strategy for treatment is adequate site preparation and prompt regeneration. To give tree seedlings the advantage, some tree cover should be maintained to protect new seedlings and prevent the profuse flowering that occurs whenever the canopy is opened. Further, duff should be reduced or removed so that germination and survival of conifers are enhanced.

211. MADANY, M.H., and N.E. WEST. 1983. Livestock grazing-fire regime interactions within montane forests of Zion National Park, Utah. Ecology 64:661-667.

Major differences were found between the vegetation structure of communities dominated by ponderosa pine (*Pinus ponderosa*) on the Horse Pasture Plateau and those on the nearby but isolated Church and Greatheart Mesas in Zion National Park. The Horse Pasture Plateau was heavily grazed by livestock in the late nineteenth and early twentieth centuries, whereas the mesas were never grazed. Conditions on the mesas now approximate those of the pre-European period, as described in the earliest written accounts. Pine, oak (*Quercus gambelii*), and Rocky Mountain juniper (*Juniperus scopulorum*) were much higher on the plateau than on the mesas. Herbaceous species dominated the ground layer of ponderosa pine on the mesa savanna stands, whereas grass and forb cover were low on analogous sites of the plateau. Since no fires were recorded on Church Mesa between 1892 and 1964, and yet sapling density had not increased, the increased understory density of plateau stands should not be attributed primarily to cessation of fires. Instead, heavy grazing by livestock and associated reduction of the herbaceous ground layer promoted establishment of less palatable tree and shrub seedlings. Fire, however, played an important secondary role in maintaining savanna and woodland communities.

212. McCLURE, N.R. 1958. Grass seedings on lodgepole pine burns in the northwest. Journal of Range Management 11:183-186.

Orchardgrass (*Dactylis glomerata*), smooth bromegrass (*Bromus inermis*), and tall oatgrass (*Arrhenatherum elatius*) became readily established in field-scale grass seedings, and by the second year provided excellent ground cover and considerable forage for livestock. The author suggests that seed source and climatic conditions are the primary factors influencing forest regeneration, with the competitive effect of perennial grass cover subordinate to, and modified by, these two major influences.

213. McCONNELL, B.R., and J.G. SMITH. 1970. **Response of understory vegetation to ponderosa pine thinning in eastern Washington. Journal of Range Management 23:208-212.**

Thinning of ponderosa pine (*Pinus ponderosa*) caused highly significant increases in understory vegetation. After eight growing seasons, total understory yield increments ranged from 75 lb/ac on unthinned plots to 417 lb/ac under 26-foot pine spacing. The increase comprised 51% grasses, 37% forbs, and 12% shrubs. When pine canopy exceeded about 45%, forbs produced more than grasses; below 45%, grasses were superior producers. Shrubs were the least productive at all levels.

214. **McDONALD, P.M. 1983. Weeds in conifer plantations of northeastern California ... management implications. P. 70-78 *In* Management of the Eastside Pine Type in Northeastern California., Susanville, California. T. F. Robson and R. B. Standiford, eds. Northern California Society of American Foresters, Arcata, California.**

Woody plants of *Arctostaphylos*, *Ceanothus*, *Artemisia*, and *Chrysothamnus* and grasses of the genera *Bromus*, *Stipa*, *Festuca*, *Sitanion*, and *Taeniatherum* are the major weeds affecting pine plantations in the eastside pine type. Crown cover of 5-year-old ponderosa pine (*Pinus ponderosa*) seedlings was greater when released by cutting of shrubs and increased significantly when a 4-foot radius around seedlings was cut and grubbed. One of the most serious grassy weeds, cheatgrass (*Bromus tectorum*), begins root growth at soil temperatures too cold for pine growth and therefore has a phenological advantage in the cold soils of the region. Control may be possible if more valuable grass species that compete with cheatgrass are used.

215. **McDONALD, P.M., and G.O. FIDDLER. 1986. Weed treatment strategies to control losses in ponderosa pine plantations. P. 47-53 *In* Forest Pest Management in Southwest Oregon: Proceedings of a Workshop, Grants Pass, Oregon. O. T. Helgerson, ed. Oregon State University, Corvallis, Oregon.**

Woody and herbaceous weeds threaten survival and growth of ponderosa pine (*Pinus ponderosa*) in southern Oregon and north-central California. Competition from weeds is severe during ponderosa pine establishment. After establishment, shrubs affect growth negatively when they make up at least 10 to 30% of the crown cover. Strategies for weed prevention and control, including cultural and chemical techniques and grazing, are considered.

216. **McLEAN, A., and M.B. CLARK. 1980. Grass, trees, and cattle on clearcut-logged areas. Journal of Range Management 33:213-217.**

Between 1971 and 1974, eight areas in the Engelmann spruce/subalpine fir (*Picea engelmannii/Abies lasiocarpa*) and Douglas-fir (*Pseudotsuga menziesii*) zones of British Columbia were clearcut and seeded with a mixture of grasses; unseeded strips were left as controls. Some areas were restocked with Engelmann spruce and lodgepole pine (*Pinus contorta*). Height growth was measured after 6 years for spruce and pine planted as 2-year-olds and after 4 years for naturally regenerating pine in grazed and ungrazed areas; there were no consistent differences resulting from grazing or seeding with grass. Data on grass production, forage utilization and cattle performance were also collected. Although cattle did cause appreciable conifer mortality (20 to 56%, mainly by trampling, rather than browsing), adequate stocks remained. There was no consistent difference in cattle-caused mortality between grass-seeded and unseeded areas and no significant relation between cattle-caused mortality and amount of forage utilization.

217. **McLEAN, A., M.B. CLARK, D.E. WALDERN, and M.T. WALLACE. 1978. Grass, trees, or cattle. Canada Agriculture 23:24-26.**

The results of studies carried out by Agriculture Canada and the B.C. Ministry of Forests are summarized. The authors conclude that damage to coniferous seedlings is negligible where numbers of cattle and

period of grazing are adequately controlled. The presence of domestic grass generally had little effect on germination or survival of conifers.

218. **McLEOD, S.D., and J.M. MANDZAK. 1990. Site preparation using Velpar L® increases juvenile growth of lodgepole pine on Montana fee lands. Champion International Corporation, Milltown, Montana. Research Note WO-90-1. 14 p.**

A study of the use of several chemical herbicides in site preparation in grass-dominated communities was initiated in 1983. This report compares size and growth characteristics of planted trees from treatments using one of those herbicides, Velpar L®, with trees from the untreated controls, after six or seven growing seasons. Velpar L® was applied at two rates, in the spring or fall. Lodgepole pine (*Pinus contorta*) seedlings were planted into the treated areas before, immediately after, and one season after herbicide application. Spring application of Velpar L® at 4 lb a.i./ac resulted in the largest and fastest growing trees for every variable measured, regardless of planting date. All treatments demonstrated significant growth increases over the controls. Height and leader growth, stem caliper, and vigor varied significantly between treatments and controls.

219. **MILLER, D.L. 1986. Conifer release in the Inland Northwest — effects. P. 17-24 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

Conifer release is the selective control of competing forest vegetation in a plantation or naturally regenerated stand. When properly used, release or maintenance treatments are timed to control competing vegetation before survival or growth losses have occurred.

Competing vegetation in grass communities should be treated during site preparation. Release treatments applied soon after planting may as much as double survival and height growth. Grasses and forbs should be controlled when canopy coverage exceeds 50%. Sites with low rainfall or soils with poor moisture-holding capacity may require treatment at lower coverage levels. More data are needed that better describe the effects of shrub, forb, and grass competition on tree seedlings. Research tests should be established in selected stands throughout the Northwest so that tree growth responses can be modeled.

220. **MILLER, D.L. 1988. The influence of competing vegetation in ponderosa pine forests. P. 115-120 *In* Ponderosa Pine: The Species and its Management, Symposium Proceedings, Spokane, Washington. D. M. Baumgartner and J. E. Lotan, eds. Washington State University, Pullman, Washington.**

Competition for limited soil moisture can severely limit ponderosa pine (*Pinus ponderosa*) regeneration success and lengthen rotations in established stands. Where grass competition is severe, at least 70% control must be achieved to ensure survival. Scalps must be at least 2 feet across to be effective where competition is severe.

221. **MILLER, R.F., and W.C. KRUEGER. 1976. Cattle use on summer foothill rangelands in northeastern Oregon. Journal of Range Management 29:367-371.**

In forested foothills at 3300- to 4000-foot elevation, production of herbage and utilization by cattle, mule deer (*Odocoileus hemionus hemionus*), and elk (*Cervus canadensis nelsonii*) were greatest in clearcut forest communities with sown forage, intermediate in bunchgrass communities (including ponderosa pine/wheatgrass [*Pinus ponderosa/Agropyron spicatum*]), and least in forested communities (ponderosa pine/snowberry [*Symphoricarpos albus*], Douglas-fir [*Pseudotsuga menziesii*]/snowberry, and grand fir/pathfinder [*Abies grandis/ Adenocaulon bicolor*]). Forage production decreased with increasing canopy cover and with decreasing soil depth. Utilization by cattle increased as distance to water and salt sources decreased. There was no direct competition for forage between cattle and big game, both of which grazed chiefly on sown grasses, because deer moved to higher altitudes before cattle grazing started in late summer.

222. MILLER, R.F., W.C. KRUEGER, and M. VAVRA. 1981. **Deer and elk use on foothill rangelands in northeastern Oregon. Journal of Range Management 34:201-204.**

Forested foothills of the Wallowa Mountains in northeastern Oregon provide spring and early summer range for deer and elk. Deer and elk use varied between plant communities and seasonally within plant communities. Plant species composition of big game diets also varied with season. Bunchgrass and logged communities, collectively occupying 57% of the land area studied, provided 90% of the big game diet during spring and early summer. Grasses made up 52% of the diet, forbs 38%, and browse 10%. Timothy (*Phleum pratense*) and western goatsbeard (*Tragopogon dubius*) were the most important species consumed by big game.

223. MITCHELL, J.E., and R.T. RODGERS. 1985. **Food habits and distribution of cattle on a forest and pasture range in northern Idaho. Journal of Range Management 38:214-220.**

Feeding behavior of a cow/calf herd on forest rangeland dominated by ponderosa pine (*Pinus ponderosa*) and smooth brome (*Bromus inermis*) in northern Idaho was studied in 1977 and 1978. Grass and browse species, the major components of the diet in both years, comprised 52.9 to 60.7% and 33 to 39% of the diet, respectively. The major browse species were mallow ninebark (*Physocarpus malvaceus*) and oceanspray (*Holodiscus discolor*); the main grasses grazed were smooth brome, common brome (*B. hordeaceus*), pinegrass (*Calamagrostis rubescens*), timothy (*Phleum pratense*) and bluegrass (*Poa* spp.). Browse species were selected more frequently in the wet year of 1978 than in the drought of 1977, even though pasture production was much greater in 1978.

224. MONFORE, J.D. 1983. **Livestock — a useful tool for vegetation control in ponderosa pine and lodgepole pine plantations. P. 105-107 *In* Forestland Grazing: Proceedings of a Symposium, Spokane, Washington. B. F. Roche, Jr. and D. M. Baumgartner, eds. Washington State University, Pullman, Washington.**

Forest managers minimized damage on pine plantations by quantifying forage production, controlling the timing of grazing and the placement and numbers of livestock, and maintaining effective herd distribution. Grazing also controlled understory vegetation, reduced fire hazard, and increased potential growth of planted pines.

225. MONFORE, J.D., and A. STENINGER. 1986. **A livestock grazing technique for pine plantations. P. 245 *In* Rangelands: A Resource Under Siege, Proceedings of the second International Rangeland Congress, Adelaide, Australia. Australian Academy of Science, Canberra, Australia.**

Use of grazing management to reduce fire hazards and control herbaceous competition with trees was tested on 500,000 acres of ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*Pinus contorta*) plantations in eastern Oregon and on substantial acreages of public lands. Herds were increased by 25 to 700%, the livestock were placed directly into the plantations earlier in the year than was traditional, and 110 new water sources were constructed on or near the plantations. Riders were used to maintain distribution of livestock on the plantations early in the season and defer grazing of riparian meadows until August. Increased riding and use of temporary fences resulted in uniform forage use.

226. **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.**

Because of insufficient clear data and conflicting interpretations of casual observations, a study of effects of slash burning on regeneration was begun on paired plots located in the Cascade and Coast Ranges of Oregon and Washington. Four classes of severity were defined: unburned, light burn, moderate burn, and severe burn. During the first few years after a slash fire, herbaceous plants appeared unable to grow on the larger patches of severely burned soil. In contrast, they quickly covered adjacent areas that were moderately or lightly burned. In the Cascades, fireweed (*Epilobium angustifolium*) and trailing blackberry (*Rubus macropetalus* [= *ursinus*]) predominated in the herbaceous cover on a large proportion of the pairs of plots and showed no preference for either burned or unburned ground. In the coastal area, western sword-fern (*Polystichum munitum*) from the original forest cover predominated in the herbaceous cover on several plots and appeared more frequently on unburned than on burned ground. Herb foliage covered about the same proportion of area on burned and unburned ground. In the Cascades, herbs covered about 30% of the area by the fourth season and changed little in the next few seasons. In the coastal area they covered a greater percentage of the ground.

227. **MORRIS, W.G. 1970. Effects of slash burning in overmature stands of the Douglas-fir region. Forest Science 16:258-270.**

After clearcutting of old-growth coniferous forests in western Washington and Oregon, pairs of burned and unburned plots were established in order to determine the effects of normal fall slash burning. Fires consumed nearly all fine fuel, left nearly all logs, and severely burned less than 6% of the soil surface. Five years after burning, the estimated rating of fire spread on the burned plots was 27% of that on the unburned, and estimated resistance to control was 67%. Difference in rate of spread ended at 16 years; difference in resistance to control ended at 12 years. Burning changed species composition of brush and herbage and reduced brush cover for a few years, except where *Ceanothus* spp. invaded. However, burning did not affect total herbaceous cover. Burning did not affect ultimate quantity of natural stocking with commercial conifers that became established after logging.

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

Many different forms of weeding are practiced in forest plantations. The most common technique is that of scalping around planted seedlings, but furrowing, scarification, and cultivation are also commonly practiced. Only recently have selective chemical treatments been developed such that weeds could be controlled without injuring seedlings and without working the soil. Several herbicides have been developed that permit substantial weed control in conifer plantations without injuring conifers planted either before or after spraying. Probably the most important practice developed in this regard has been the broadcast application of atrazine over conifer plantations in the Pacific Northwest. Application methods, dosage rates, and plantation effects of atrazine are reviewed.

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

Atrazine at rates as low as 2 lb/ac gave good control of grasses in 2-year-old plantings of Douglas-fir (*Pseudotsuga menziesii*), though the addition of 2,4-D at 0.5 lb/ac was required to control broad-leaved weeds, including false dandelion (*Pyrrhopappus carolinianus*). No advantage was gained by adding a wetter, but cacodylic acid appeared to act synergistically with atrazine, considerably increasing the speed of plant response. A combination of atrazine + 2,4-D + cacodylic acid proved particularly effective and, like the other treatments tested, was nontoxic to the conifers, irrespective of whether spraying was done before or after planting.

230. NEWTON, M. 1981. **Chemical management of herbs and sclerophyll brush. P. 50-65 *In* Reforestation of Skeletal Soils: Workshop Proceedings, Medford, Oregon. S.D. Hobbs and O.T. Helgerson, eds. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.**

Competing vegetation in conifer plantations consistently affects conifer growth negatively, especially in early years. Treatments to release conifers improve growth effectively when applied before competition becomes severe. Release with chemicals may cause injury, but conifers recover within 2 years, except when treated with picloram. Chemical treatments are available that appear noninjurious to Douglas-fir (*Pseudotsuga menziesii*). Appropriate site preparation can reduce or eliminate the need for release. Two extensive tables show the properties of herbicides commonly used in southwest Oregon and the herbicides to select for various vegetation types. Dalapon, atrazine, 2,4-D, and hexazinone are recommended to control grasses and forbs for site preparation; hexazinone, pronamide, and simazine are recommended for release. For control of fems, glyphosate and asulam are recommended for site preparation and release, and dicamba only for site preparation.

231. **NEWTON, M., and E.C. COLE. 1989. Where does sulfometuron fit in Pacific Northwest silviculture? Proceedings, Western Society of Weed Science 42:121-128.**

Sulfometuron has been suggested to control a broad spectrum of weeds selectively in a single application with negligible damage to conifers. In a series of aerial application plots, sulfometuron was applied alone and compared with hexazinone and atrazine + glyphosate at several rates.

When all sites were considered together, all treatments significantly reduced plant cover compared to untreated controls. Forbs, grass, shrubs, and trailing blackberry were all reduced by all chemical treatments, but fern cover was not significantly reduced. When 2,4-D was added to sulfometuron, forbs and trailing blackberries were significantly reduced.

Individual species groups varied greatly in their sensitivities. Pearly everlasting (*Anaphalis margaritacea*), bedstraw (*Galium aparive*), fireweed (*Epilobium angustifolium*), and false hellebore (*Veratrum insolitum*) were highly resistant and appeared after treatment. Figwort (*Scrophularia californica*) and foxglove (*Digitalis purpurea*) were nearly eradicated by sulfometuron with or without 2,4-D; thistles (*Cirsium* spp.) were reduced by sulfometuron and nearly eradicated when 2,4-D was added. Although there were no significant differences in sword-fern (*Polystichum munitum*) cover among treatments, those treated with sulfometuron appeared lower in vigor and were expected to decline the following year.

232. **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.**

Seedling growth in Douglas-fir (*Pseudotsuga menziesii*) during the first 5 years after planting was increased by controlling grasses and forbs in seven herbicide regimes during the first 3 years. The greatest effect from 1 year of weeding was from first-year weed control; growth increases attributable to early weeding continued through the fifth year. Devegetated plots had more available moisture through the growing season than those with bentgrass (*Agrostis tenuis*) or forb/grass mixtures dominated by bentgrass and cat's ears (*Hypochaeris radicata*) cover, in that order. Weed control relieved moisture stress in trees, increasing the number of hours each year when stress was compatible with photosynthesis. Douglas-fir photosynthesis tends to shut down in the vicinity of −2.0 MPa moisture stress. Plotting the number of MPa-hours above −2.0 MPa during the first 3 years after planting explained 77% of the variation in fifth-year biomass of Douglas-fir. In a favorable coastal environment, about 1,700 MPa-hours above −2.0 MPa are necessary in the first 3 years for survival; increments of moisture beyond that should contribute significantly to growth.

233. **NEWTON, M., and W.L. WEBB. 1970. Herbicides and the management of young pine. P. 94-99 *In* Regeneration of Ponderosa Pine, Symposium Proceedings, Corvallis, Oregon. School of Forestry, Oregon State University, Corvallis, Oregon.**

The limited information in the literature suggests that herbicides applied successfully in regeneration of Douglas-fir (*Pseudotsuga menziesii*) may generally be considered effective and safe for use in regeneration of ponderosa pine (*Pinus ponderosa*). Control of herbaceous weeds sufficient to permit establishment should be obtainable with atrazine, dalapon, or both. Problems of brush control are discussed. Chemical thinning of young ponderosa pine stands with MSMA (monosodium methane arsonate) or cacodylic acid is recommended.

234. **NORDSTROM, L.O. 1985. The ecology and management of forest-range in British Columbia: a review and analysis. British Columbia Ministry of Forests, Victoria, British Columbia. Land Management Report 19. 104 p.**

The literature on forest grazing throughout North America is synthesized, and the applicability of results from geographically widespread studies to the situation in British Columbia is assessed. Research needs are identified.

235. **O'CONNELL, B. 1983. Forestland grazing on Boise Cascade Corporation owned lands in northeast Washington. P. 97-99 *In* Forestland Grazing: Proceedings of a Symposium, Spokane, Washington. B.F. Roche, Jr. and D.M. Baumgartner, eds. Washington State University, Pullman, Washington.**

Boise Cascade Corporation manages approximately 256,000 ac of forestland in northeast Washington, much of which is scattered ownership and open range. The land is best adapted to even-aged management utilizing seed trees, shelterwood, and clearcutting to regenerate stands. Unrestricted grazing during regeneration causes much damage and sometimes prevents establishment of the new forest. This conflict has caused Boise Cascade to attempt to gain control of grazing on its lands and to lease grazing to only those cattlemen who are willing to restrict their cattle to areas with trees 15 years old or more.

236. **OHLROGGE, L. 1986. Use of Roundup® for site preparation on the Lincoln Ranger District, Helena National Forest, Montana. P. 133-134 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D.M. Baumgartner, R.J. Boyd, D.W. Breuer, and D.L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.**

Spot ground application of Roundup® was done on 343 ac of backlog reforestation in the summer of 1983. The primary species to be controlled were pinegrass (*Calamagrostis rubescens*), snowberry (*Symphoricarpos albus*), elk sedge (*Carex geyeri*), serviceberry (*Amelanchier alnifolia*), and blue bunch wheatgrass (*Agropyron spicatum*). The herbicide formulation was 2 qt Roundup® + 6.5 oz of surfactant/10 gal water. Within 2 weeks after treatment, at least 90% of the vegetation in the treated spots was brown. The cost for the contract was $80/ac, which included marking the treated spots. Examination in August showed 80% survival of lodgepole pine, ponderosa pine, and Douglas-fir.

237. **PASE, C.P. 1958. Herbage production and composition under immature ponderosa pine stands in the Black Hills. Journal of Range Management 11:238-242.**

A survey in 1956 produced a logarithmic relationship between total herbage production and pine crown canopy, stand basal area, and pine litter. Total herbage production ranged from 40 lb/ac (air-dry) under a 70% crown canopy to 2,160 lb/ac on clearcut areas. Grass, forb, and shrub production on clearcut areas was 1,730, 305, and 125 lb/ac (air-dry), respectively, compared with only 25, 5, and 10 lb/ac under dense unthinned stands. Under thinned stands with a crown canopy of 40%, grass, forb, and shrub production was 170, 25, and 30 lb/ac (air-dry), respectively. Data on the influence of crown canopy on species composition are presented.

238. PASE, C.P., and R.M. HURD. 1958. **Understory vegetation as related to basal area, crown cover and litter produced by immature ponderosa pine stands in the Black Hills.** P. 156-158 *In* Proceedings, Society of American Foresters Meeting 1957, Syracuse, New York. Society of American Foresters, Washington, D.C.

Herbage production under ponderosa pine (*Pinus ponderosa*) stands in the Black Hills was determined. Production of grasses, forbs, and shrubs all increased as basal area and crown density of the pine overstory and pounds of litter per acre decreased. Total herbage production ranged from 22 lb/ac (air-dry) at a basal area of 200 ft^2/ac to 1,660 lb/ac at 0 basal area (clearcut areas). Under these timber conditions, grasses increased from 13 to 1,330 lb/ac, forbs from 2 to 210 lb/ac, and shrubs from 7 to 120 lb/ac. Composition of the herbaceous understory changed as basal area increased. The more shade-tolerant species assumed greater importance as basal areas increased, and less tolerant species disappeared. Production of both herbaceous and shrubby vegetation increased as pine stands became more open. Thinning to and beyond accepted silvicultural standards may be one way to improve browse production on important deer winter ranges.

239. PEARSON, H.A., J.R. DAVIS, and G.H. SCHUBERT. 1972. **Effects of wildfire on timber and forage production in Arizona.** Journal of Range Management 25:250-253.

A severe wildfire in May decimated an unthinned ponderosa pine (*Pinus ponderosa*) stand in northern Arizona; an adjacent thinned stand was relatively undamaged. Radial growth increased on burned trees where crown kill was less than 60% and decreased where crown kill was more than 60%. Burning initially stimulated growth of herbaceous vegetation in both stands and temporarily enhanced nutrient value of herbage. Artificially seeded areas produced most herbage 2 years after burning.

240. PETERSEN, T.D. 1982. **First-year survival and growth of ponderosa pine after post-planting applications of Velpar® and Roundup®.** Champion International Corporation, Milltown, Montana. Research Note RM-82-1. 15 p.

Field trials of chemical site preparation were conducted for sites dominated by grass and other herbaceous weeds. First-year tests of Roundup® and Velpar® for use with spring planting of 2-0 ponderosa pine (*Pinus ponderosa*) were completed. Velpar® was safe and effective and significantly increased survival and growth. Because of toxicity to conifers and lack of season-long grass control, Roundup® was not effective and should not be used as a post-planting application. Artificial shade did not improve survival or growth on south aspects if grass was controlled with herbicides. Hand scalping was not as beneficial as applications of Velpar®. Broadcast applications decreased competition from seedlings more than did spot applications around individual seedlings.

241. PETERSEN, T.D. 1982. **Guidelines for using Velpar® for site preparation in Montana based on second-year research trials.** Champion International Corporation, Milltown, Montana. Research Note RM-82-9. 8 p.

This note presents recommendations for using Velpar® based on the latest results from research conducted in the Rocky Mountains Timberlands Division of Champion International Corporation. Pinegrass (*Calamagarostis rubescens*) and elksedge (*Carex geyeri*) were the primary focus of the trials.

Dormant season applications can be made either in late fall or in early spring. At rates higher than 1.5 lb/ac, there was little difference between the two application times. At 1.0 lb/ac, however, spring applications controlled both species better. Excellent first-year control of pinegrass and elksedge was achieved at rates of 1.5 lb/ac, but there appeared to be little reason to apply more than 2.0 lb/ac on most sites.

Velpar® consistently improves survival of ponderosa pine (*Pinus ponderosa*) on sites where grass competition is a major cause of mortality. However, the magnitude of this response varies between sites and

between years. Greater responses can be expected on drier sites or in years when grass competition causes greater mortality. Velpar® caused considerable mortality in container seedlings of larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*). Until injury can be predicted with more certainty than is possible at present, Velpar® should not be used on sites where container seedlings of larch or Douglas-fir will be planted.

242. **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.**

During the summer of 1978, trials were established in four 5-year-old plantations and four 10-year-old plantations in the Oregon Cascades. Each site was well stocked with Douglas-fir (*Pseudotsuga menziesii*) and had a moderate to heavy cover of snowbrush (*Ceanothus velutinus*) and forbs. Herbaceous vegetation consisted mostly of fireweed (*Epilobium angustifolium*), trailing blackberry (*Rubus ursinus*), and bracken fem (*Pteridium aquilinum*). Treatments applied were (1) no release; (2) application of a 5% solution of Esteron 99® concentrate in diesel oil to the lower stems of snowbrush, with no control of herbs; (3) treatment of herbs with a broadcast application of a 1% solution of glyphosate in water, in addition to the application of Esteron 99® concentrate to the snowbrush; and (4) manual release by cutting the shrubs near the ground with a chain saw.

The relative increase in the growth of Douglas-fir after release depended on the extent to which competing vegetation was controlled, the age of the trees when released, and the method of release. Control of herbaceous vegetation and snowbrush resulted in the greatest stem diameters and volumes after 5 years in both age classes. Growth suppression caused by vegetation other than snowbrush was also reflected in stem height after 5 years. Control of snowbrush without concurrent control of fireweed, blackberry, and bracken fem failed to improve height growth significantly in the 10-year-old plantations.

Release treatments should be directed toward both shrubs and herbaceous weeds at an early age. Preferably, free-to-grow conditions should be provided for conifers from the time of planting.

243. **PETTIT, R.D. 1968. Effects of seeding and grazing on a clearcut-burn in a mixed-coniferous forest stand of the Wallowa Mountain foothills. Ph.D. dissertation, Oregon State University, Corvallis, Oregon. 142 p.**

Early plant succession, grazing influences on native and introduced species, big game use, and environmental relationships were studied in a mixed-conifer forest stand that had been clearcut, burned, and seeded. Seedlings included a mixture of timothy (*Phleum pratense*), orchardgrass (*Dactylis glomerata*), tall oatgrass (*Arrhenatherum elatius*), smooth brome (*Bromus inermis*), white Dutch clover (*Trifolium repens*), and two pure stands of mountain brome (*Bromus marginatus*) and blue wildrye (*Elymus glaucus*). Research was carried out from 1965 to 1967 in three 5-ac exclosures that had been constructed after treatment in 1963 and 1964. Four major tree species — Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), western white pine (*Pinus monticola*) and western larch (*Larix occidentalis*)—were planted at a rate of 880 trees/ac. Minor quantities of grand fir (*Abies grandis*), lodgepole pine (*Pinus contorta*), and Engelmann spruce (*Picea engelmannii*) were planted to bring the total population to 1000 trees/ac.

Bull thistle (*Cirsium vulgare*) was the most abundant species in early stages of succession. Foliage cover of this species was reduced significantly when competing with introduced grass seedings. Most thistle and other weedy production were confined to unseeded plots.

Yearling replacement heifers stocked at approximately 1 animal unit/ac were grazed in both cattle exclosures. Heifers preferred Ross' sedge (*Carex rossii*), orchardgrass, blue elderberry (*Sambucus cerulea*), and Canada milkvetch (*Astragalus canadensis*). Different preferences might be noted if an earlier grazing season were used. Some browsing of tree seedlings occurred in 1967, but this was believed to result from an excessive concentration of animals.

The author concludes that grazing and forest management are compatible and essential to maximize profits from the mixed-conifer forest of northeast Oregon. Because these results were preliminary, no specific management plans were developed.

244. 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.**

A grazing trial with a band of 800 dry ewes was conducted on 10- to 15-year-old clearcut units in the western Cascades in the summer of 1978. Vegetation production and sheep utilization samples were collected. Fireweed (*Epilobium angustifolium*) comprised 70 to 80% of the total production. *Vaccinum* spp. and *Rubus* spp. composed the next largest proportions of the available vegetation. Herbaceous and shrubby species composed the greatest bulk of vegetation taken and 70 to 80% of the total diet. Sheep did not use conifers unless they were held on an area for an extended period.

245. POULSEN, W.G. 1964. **Weed control in Utah conifer tree plantings. Utah Farm and Home Science 25:22-23.**

Simazine (80W) was tried on soils varying from loam to clay-loam and planted with Colorado blue spruce (*Picea pungens*), eastern redcedar (*Juniperus virginiana*), ponderosa pine (*Pinus ponderosa*), and Douglas-fir (*Pseudotsuga menziesii*). Four areas were sprayed in November and one in May. Various dosages were applied in 6 gal water/1000 ft^2. The trees were in their second growing season on three areas and in their fifth on the remaining ones. Ponderosa pine became chlorotic when 1.24-1.75 oz/1000 ft^2 were used in November, but suffered no ill effects from 2 oz/1000 ft^2 in May. For annual weeds, 0.5 oz/1000 ft^2 was adequate. Little additional effect was gained from rates >1.25 oz/1000 ft^2. Ground cherry (*Physalis subglabrata*) was not controlled even at 1.75 oz/1000 ft^2. In general, application of 1 oz/1000 ft^2 is recommended for light soils low in organic matter, and 1.25 oz/1000 ft^2 is recommended for heavy clay and loam soils. These rates are appropriate for almost any season, although application in autumn is preferable where winter annuals are to be controlled.

246. PREEST, D.H., and N.A. DAVENHILL. 1969. **Selective chemical control of grass in young radiata pine and Douglas-fir has promise. New Zealand Forest Service, Forest Research Institute, Rotorua, New Zealand. Research Leaflet 21. 4 p.**

Aerial application of 23 substances to control grasses and herbaceous weeds was tested in plantations of radiata pine (*Pinus radiata*) and Douglas-fir (*Pseudotsuga menziesii*) in New Zealand. Young transplants withstood high rates of Prefix® granules and foliar applications of simazine, propazine, and atrazine in mid-February with little or no ill effect. Casoron® granules and 2,2-DPA were also effective.

247. QUINTON, D.A. 1984. **Cattle diets on seeded clearcut areas in central interior British Columbia. Journal of Range Management 37:349-352.**

The bite-count technique was used to estimate the botanical composition of cattle diets for deferred rotation and continuous grazing systems on seeded forest range previously clearcut of Engelmann spruce (*Picea engelmannii*) and lodgepole pine (*Pinus contorta*). Diets varied more among grazing periods and years within grazing systems than between grazing systems. Grasses, forbs, and shrubs averaged 58.7%, 33.5% and 9% of the diet, respectively. Orchardgrass (*Dactylis glomerata*), timothy (*Phleum pratense*), bromegrass (*Bromus inermis*), horsetail (*Equisetum* spp.), lupine (*Lupinus* spp.), aster (*Aster* spp.), and willow (*Salix* spp.) were the major forage species consumed. Diets changed moderately from July through August, with a more pronounced change in September. With advanced maturity of grass during dry years, forb usage increased, in some instances to as much as 54% of the diet.

248. **RAY, J.W., A.L. VANNER, and B. RICHARDSON. 1986. Effect of application volume and spray additive concentration on the control of bracken. Proceedings of the New Zealand Weed and Pest Control Conference 39:89-91.**

Hardened mature bracken (*Pteridium aquilinum*) was sprayed aerially at application volumes of 220 and 20 l/ha, with either glyphosate or asulam plus various spray additives. Silwet M® was the most effective additive tried. Herbicide effectiveness increased with increased amounts of Silwet M®, irrespective of application volume. Application volumes possibly could be reduced for aerially applied sprays for bracken control.

249. **REID, E.H. 1965. Forage production in ponderosa pine forests. P. 61-64 *In* Proceedings, Society of American Foresters Meeting 1964, Denver, Colorado. Society of American Foresters, Washington, D.C.**

Forests of ponderosa pine (*Pinus ponderosa*) are a valuable forage resource for cattle, sheep, and big game. Herbage and browse production varies drastically with density of tree overstory, as do utilization and probably nutritional value of the usable understory. Therefore, the grazing value is determined by how the tree overstory is managed. Timber cutting reduces forage and browse production immediately because of ground disturbance and slash cover. In the long term, forage production probably is increased by the opening of the tree canopy. Seeding barren areas created by logging and burns to adapted grasses and legumes is a desirable method of increasing livestock and game forage. Such seedings can be detrimental to tree reproduction and therefore may be undesirable where growing trees is the primary land use. Close attention to the problems of multiple-use management is imperative for combined production of trees, livestock, and wildlife.

250. **REYNOLDS, H.G. 1962. Effect of logging on understory vegetation and deer use in a ponderosa pine forest of Arizona. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note 80. 7 p.**

Vegetation and deer use were compared in unlogged forests and in forests that had been logged in 6 of 10 years. During the first year after logging, forbs and aspen sprouts increased, but sedges and perennial grasses produced less, possibly because of mechanical disturbance during logging. From the second through the sixth year, production of all understory vegetation increased annually. Thereafter, all types declined in production except aspen sprouts, which were still increasing 11 years after logging. At the end of 11 years, total production of understory herbage was still slightly higher on the logged area. The tentative conclusion was that production of understory vegetation on selectively logged ponderosa pine (*Pinus ponderosa*) lands on the North Kaibab can be expected to exceed that on unlogged lands for 11 to 15 years.

251. **REYNOLDS, H.G. 1969. Aspen grove use by deer, elk, and cattle in southwestern coniferous forests. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-138. 4 p.**

Aspen (*Populus tremuloides*) groves in mixed-conifer forests of Arizona yielded about six times more herbaceous plants in the understory than did adjacent mixed-conifer forest. Thinning patches of aspen and associated coniferous reproduction in forests of ponderosa pine (*Pinus ponderosa*) to about three-fourths basal area produced about two and one-half times as much herbaceous understory and increased production of aspen sprouts four-fold. Preserving or providing for an interspersion of aspen groves in a mixed-conifer forest should improve habitat for deer effectively.

252. **RICHESON, R.A. 1977. Understory response to overstory thinning in stagnated mixed-conifer forests of central Washington. M.S. thesis, Washington State University, Pullman, Washington. 42 p.**

This study was conducted in the summers of 1973 through 1975 in the Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) zones of central Washington. The major objective was to determine effects of reducing tree stocking in overstocked mixed-conifer forests on understory production for domestic livestock and big game. Tree stocking was reduced to various levels on 22 1-ac plots. Each plot then was subdivided into four 0.25-ac subplots; each subplot received one of the following treatments: (1) seeding only, (2) seeding and fertilization, (3) fertilization only, and (4) control.

Analysis of the data collected before reducing tree stocking revealed a significant correlation between understory productivity, litter depth, and canopy coverage. Increases in either litter depth or canopy coverage were associated with declines in both understory productivity and understory species composition.

Understory production increased from 22.8 lb/ac before treatment to 242.6 lb/ac one growing season after treatment in the Douglas-fir forest and increased from 89.3 lb/ac to 387.9 lb/ac in the ponderosa pine forest. Understory production increased most substantially in stands reduced to 50 trees/ac, followed in order by stocking rates of 0, 100, and 200 trees/ac. Significantly higher yields were obtained from subplots that were either seeded and fertilized or fertilized only, as compared to subplots that were untreated or seeded only. Fertilization may provide the necessary impetus for successful grass seedings.

Thinning of these overstocked mixed-conifer forests did substantially increase understory production and, therefore, grazing capacities for cattle and big game.

253. **RIES, R.E. 1968. Herbage and timber production under a western Montana pine canopy. M.S. thesis, University of Montana, Missoula, Montana. 94 p.**

During the summer of 1967, data were collected in Lolo National Forest, Montana, on herbage production (all grass and grasslike plants, shrubs, and forbs), tree reproduction, and tree growth under four canopy classes of ponderosa pine (*Pinus ponderosa*). Soil temperature, soil moisture, ground cover, and tree seed production under these canopies were also measured. The object was to measure the pounds per acre of herbage and forage being produced in each class. Canopy classes were established by measuring the percent canopy cover with a spherical densiometer at 65 selected canopy points. The 65 points were then placed into one of the 4 canopy classes (first, 1-10%; second, 11-30%; third, 31-50%; fourth, 51-70%).

Herbage production changed little as canopy cover increased. Herbage production was 468 lb/ac in the first canopy class, 488 lb/ac in the second, and 400 lb/ac in both the third and fourth classes. Total forage fluctuated in no definite pattern as canopy increased. Eighty-five lb/ac of forage were produced in the first class, 108 lb/ac in the second, 59 lb/ac in the third, and 106 lb/ac in the fourth. The grass and grasslike plants, forbs, and shrubs did not exhibit any strong trends in production patterns as canopy increased. Tree reproduction continually increased as canopy cover increased: 720 seedlings/ac were found in the first canopy class, 1,530 seedlings/ac in the second, 2,370 seedlings/ac in the third, and 2,500 seedlings/ac in the fourth.

Decreased herbage production as canopy cover increases may not be as evident under all environmental conditions. If the production is first limited by one or more factors unrelated to increased canopy cover, the net effect of canopy and its related factors on herbage production may not be evident. This area would have only minor value as a livestock grazing area, and the effect of increased canopy cover on herbage and forage production is not significant when management decisions are considered.

254. **RINDT, C.A. 1965. A silviculturist looks at grass and grazing effects on ponderosa pine. P. 69-70 *In* Proceedings, Society of American Foresters Meeting 1964, Denver, Colorado. Society of American Foresters, Washington, D.C.**

Grass principally affects regeneration of ponderosa pine (*Pinus ponderosa*) by competing for soil moisture. This competition is most critical until tree roots have grown out of the zone of moisture stress. However, grass may prevent overstocking of pine on some areas, when tree seed is abundant and site conditions are favorable. Decisions regarding the amount of grass that can be tolerated on a pine-regeneration area should be based on information about different soils and the grass-tree-soil moisture relationship on different sites. Decisions regarding grazing use of reforestation areas should be based on information on the potential for animal damage and the animal control measures necessary. Where grazing will cause intolerable damage, provisions must be adequate to control it until the trees are out of danger.

255. **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.**

A brown-and-burn site-preparation project was monitored on an alder-dominated brushfield in the western Oregon Coast Range. Prefire vegetation was surveyed, and the fuel complex created by felling and aerial application of herbicides was evaluated. Postfire vegetation was examined during the 4 months following the August 1974 fire. Two other sites similarly treated within the past 5 years were also studied, and an attempt was made to characterize early trends in plant succession after brown-and-burn treatment.

Sprouts and germinants began appearing on the project area within 2 or 3 weeks after the fire, before the first soaking rain. Bracken fern (*Pteridium aquilinum*) and sword-fern (*Polystichum munitum*) were among the first to resprout, closely followed by vine maple (*Acer circinatum*), bitter cherry (*Prunus emarginata*), and bigleaf maple (*Acer macrophyllum*). Phacelia (*Phacelia heterophylla*), soft nettle (*Stachys* spp.), thistle (*Cirsium* spp.), and geranium (*Geranium* spp.) were the earliest germinants to appear. In early September, germinants were present on 86% of the 76 burned plots. Vine maple had sprouted on 51% of the plots, and sword-fern had reappeared on 78%. Canopy coverage one month after burning was quite low — certainly below 5% — but sprouts grew rapidly in ensuing weeks, and germinants continued to appear. By mid-November, canopy coverage had increased to an estimated 9.92%, with phacelia and Cascade Oregon grape (*Berberis nervosa*) comprising 60% of the total coverage. Although canopy coverage was reduced drastically from prefire levels, many species had returned to comparable frequencies.

Vegetation on both previously treated areas had completely reoccupied the site two and five growing seasons after treatment. Ground cover averaged 50% at both sites. Foxglove (*Digitalis purpurea*) was found most frequently, followed closely by tansy ragwort (*Senecio jacobaea*), various grasses, and sword-fern.

256. **ROBOCKER, W.C. 1971. Herbicidal suppression of bracken and effects of forage production. Weed Science 19:538-541.**

Nineteen herbicides in various formulations were tested pre- and postemergence for control of western bracken (*Pteridium aquilinum* var. *pubescens*). Excellent suppression was obtained for 1 year with fall applications of granular formulations of 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. Bracken recovered rapidly after 1 year of suppression by dichlobenil, but other herbaceous species were killed. Bracken recovered considerably the second growing season after application of picloram or dicamba, although morphological effects were noticeable for 2 to 3 years, particularly from dicamba. No visual injury to grasses was apparent from picloram. Some injury to orchardgrass (*Dactylis glomerata*) was noted from dicamba.

257. ROSS, B.A. 1977. Compatibility of cattle grazing with timber production on British Columbia's interior rangelands. B.S.F. thesis, University of British Columbia, Vancouver, British Columbia. 43 p.

Literature on forest grazing in British Columbia is reviewed, with emphasis on overstory/understory relationships, grass-conifer competition, livestock damage to coniferous regeneration, forest-range seeding and fertilization, and grazing management. The author concludes that grazing and timber production can be complementary through proper management.

258. ROSS, D.W. 1985. The effects of mechanical and chemical site preparation on ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and lodgepole pine (*Pinus contorta* Dougl. ex. Loud.) performance, associated vegetation, and soil properties in southcentral Oregon eight years after planting. M.S. thesis, Oregon State University, Corvallis, Oregon. 203 p.

Six alternative site-preparation treatments were compared at three sites in southcentral Oregon. Treatments included a logged-only control, ripping, brushblading, disking, chemical, and chemical followed by disking. Plots containing bareroot and containerized seedlings of ponderosa pine and containerized seedlings of lodgepole pine were remeasured eight growing seasons after establishment. The treatments were evaluated on the basis of changes in selected soil chemical and physical properties, the response of nonconiferous vegetation, and the survival and growth of the planted pines.

Plant communities at the higher elevation sites (Swede Cabin and Camp Nine) were composed primarily of grass, sedge, and forb species with scattered shrubs. In general, canopy coverage of herbaceous vegetation at these sites was highest in control and rip plots, followed by the brushblade, disk, chemical/disk, and chemical treatments. These results emphasize the importance of controlling competing vegetation for increased survival and early growth of planted pines in southcentral Oregon.

259. ROSS, D.W. 1986. Effects of site preparation methods on ponderosa pine, lodgepole pine, associated vegetation, and soil properties in southcentral Oregon. P. 35-38 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D. M. Baumgartner, R. J. Boyd, D. W. Breuer, and D. L. Miller, eds. Washington State University, Pullman, Washington.

Six alternative site-preparation treatments were compared at three locations in southcentral Oregon. Treatment evaluation was based on changes in selected soil chemical and physical properties, the response of nonconiferous vegetation, and the survival and growth of planted ponderosa pine (*Pinus ponderosa*). Treatments included a logged-only control, ripping, brushblading, disking, chemical, and chemical followed by disking. One location, Camp Nine, contained a dense grass and sedge community with widely scattered plants of *Ceanothus* spp. Soil samples were analyzed for nutrients and bulk density was determined. In general, the brushblading and chemical/disk treatments caused the greatest reduction in nutrient levels and the greatest increase in bulk density.

Pine survival and growth were generally best where vegetation was controlled most thoroughly. Brushblading was the only treatment that deviated from this pattern. Controlling competing vegetation is important in achieving maximum survival and early growth of planted pines in southcentral Oregon.

260. ROSS, D.W., and J.D. WALSTAD. 1986. Vegetative competition, site-preparation, and pine performance: a literature review with reference to southcentral Oregon. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. Research Bulletin 58. 21 p.

Methods to control undesirable vegetation during plantation establishment (mainly of ponderosa pine [*Pinus ponderosa*]) are discussed in relation to expected silvicultural benefits and possible adverse effects of treatments on long-term site productivity. Mechanical methods are emphasized.

261. **RUMMELL, R.S. 1951. Some effects of livestock grazing on ponderosa pine forest and range in central Washington. Ecology 32:594-607.**

In ungrazed and grazed areas in central Washington, parts of the virgin ponderosa pine (*Pinus ponderosa*) forest contained dense mats of herbaceous understory vegetation and sparse stands of tree reproduction. Pinegrass (*Calamagrostis rubescens*) dominated; elk sedge (*Carex geyeri*) was a minor part of the understory virgin flora.

Densities of herbaceous understory vegetation on the ungrazed area were 183 to 254% of the densities on the grazed area. Herbage yields of pinegrass were strikingly different between the two areas. Pinegrass beneath open ponderosa pine produced 850 lb air-dry herbage/ac, compared to only 240 lb/ac on the grazed area.

The high density of herbaceous understory vegetation on the ungrazed area contributed substantially to the deficiency of advance tree reproduction. Heavy grazing of the herbaceous understory vegetation, rather than exclusion of fire, appeared to be the prime factor in explaining the dense advance tree reproduction in the grazed area.

262. **SEIDEL, K.W., J.M. GEIST, and G.S. STRICKLER. 1990. The influence of cattle grazing and grass seeding on coniferous regeneration after shelterwood cutting in eastern Oregon. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. Research Paper PNW-417. 32 p.**

Natural regeneration was abundant, regardless of grazing and grass-seeding treatments, after shelterwood cutting to three overstory densities (27, 73, and 119 ft^2 basal area/ac) in mixed-conifer stands in the Starkey Experimental Forest and Range in eastern Oregon. After 5 years, the number of tree seedlings ranged from about 3,800/ac on the low-density plots to 39,000/ac on the high-density plots and consisted of about 84% grand fir (*Abies grandis*); 10% Douglas-fir (*Pseudotsuga menziesii* var. *glauca*); and 6% ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), and western larch (*Larix occidentalis*). Neither grazing nor seeded grasses decreased seedling establishment, but grass did retard seedling height growth. The number of seedlings was greatest on mineral soil seedbeds, but stocking was adequate where light to medium amounts of litter and slash were present. A residual overstory of about 30 to 40 ft^2 basal area/ac appeared adequate to provide natural regeneration within 5 years. Seeding 4 to 5 lb of less competitive grasses and grazing up to 60% of the current year's growth were compatible with tree seedling establishment.

263. **SEVERSON, K.E., and C.E. BOLDT. 1977. Options for Black Hills forest owners: timber, forage, or both. Rangeman's Journal 4:13-15.**

Regulating tree stocking by periodic thinning of stands of ponderosa pine (*Pinus ponderosa*) promotes mixed crops of timber and forage that are substantially more productive than either type of vegetation growing alone.

264. **SHEA, M.P. 1981. Influence of seeded and fertilized grasses on regeneration of lodgepole pine. M.S. thesis, Washington State University, Pullman, Washington. 58 p.**

Following a severe wildfire in August 1970, seeding and fertilizing treatments were applied in a randomized, unreplicated plot design to test the regeneration capability of lodgepole pine (*Pinus contorta*) in competition with seeded grasses. Overstory grasses were seeded separately and in mixture with hard fescue (*Festuca ovina* var. *duriscula*), an understory grass species. Overstory species included intermediate wheatgrass (*Agropyron intermedium*), slender wheatgrass (*Agropyron trachycaulum*), pubescent wheatgrass (*Agropyron trichophorum*), smooth brome (*Bromus inermis*), orchardgrass (*Dactylis glomerata*), and blue wildrye (*Elymus glaucus*). The three fertilizer treatments included application in fall of 1970, application in fall of 1970 plus applications on alternate years until 1975, and unfertilized controls. Application rate of the fertilizer, ammonium nitrate sulfate, was 45 lb a.i./ac.

A significant negative correlation was found between number of established tree seedlings per acre and percent ground cover of perennial grasses. Hard fescue seedings resulted in the greatest ground cover and the smallest number of established pine seedlings. Seeded overstory grass species produced less ground cover and were less competitive with tree seedlings than hard fescue. In order from most to least competitive, the grasses were orchardgrass, pubescent wheatgrass, smooth brome, blue wildrye, slender wheatgrass and intermediate wheatgrass.

Forage production in 1975 averaged approximately 1 animal unit month/ac on seeded and fertilized plots, but had dropped to less than half that amount by 1980. Native pinegrass (*Calamagrostis rubescens*) increased at the expense of the seeded species, including hard fescue, from 1975 to 1980. Increasing amounts of fertilizer increased seeded grass density, reduced pine seedling establishment, and favored production of introduced grass over native pinegrass.

An abbreviated economic analysis showed that the greatest combined forage/timber revenue returns, after costs, were produced on seeded/fertilized plots where grass competition held tree reproduction to approximately 400 trees/ac and precommercial thinning was not needed.

265. SLOAN, J.P., and R.A. RYKER. 1986. **Large scalps improve survival and growth of planted conifers in central Idaho. USDA Forest Service, Intermountain Research Station, Ogden, Utah. Research Paper INT-366. 9 p.**

Three conifer species were planted and compared on a large clearcut in central Idaho. Three scalp sizes were also compared. The study site was harsh and had a history of plantation failures caused, at least in part, by heavy coverage of elk sedge (*Carex geyeri*). After 5 years, survival and height growth were greatest in lodgepole pine (*Pinus contorta* var. *latifolia*), intermediate in ponderosa pine (*Pinus ponderosa*), and least in Douglas-fir (*Pseudotsuga menziesii* var. *glauca*). On 2-foot handmade scalps, tree survival and total height were less than on 4-foot wide dozer strips. This was especially true for pines.

On hot and dry sites where elk sedge or other grasses are extremely competitive, 4-foot scalps appear to be the minimum site preparation required. Adequate site preparation, matching of proper species to the site conditions, and adequate control of livestock and gophers can help ensure success in reforesting these sites.

266. SOWDER, J.E. 1960. **Seeding grass on areas disturbed by logging or fire on east-side Oregon and Washington forests. P. 166-168 *in* Proceedings, Society of American Foresters Meeting 1959, San Francisco, California. Society of American Foresters, Washington, D.C.**

Seeding areas disturbed by logging to grass has been recommended as a way to recover lost grazing capacity, minimize invasion of undesirable and noxious plants, and minimize site deterioration caused by soil erosion. The author describes three studies by others. The first found that grass competition reduced establishment, survival, and growth of naturally regenerated pine; the heavier the grass cover, the more severe was the effect. The second study, on planted pines, recorded 56% survival on bare soil, 35% in light cover of grass and sedge, 9% in medium cover, and none in heavy cover. The last study found that brush, grass, and other vegetation reduced diameter growth by half but had little or no effect on height growth. In general, trees have a good chance of surviving when new grass and trees become established at the same time. It is the older, well-established vegetation that gives the new trees a difficult time.

However, trees also compete with other trees, and the author suggests that tree competition is more severe than grass competititon for established trees. Seeding grass or other forage plants in areas that have been thinned appears economical, as it allows the owner to produce more timber and more forage on pine forest lands.

267. **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, British Columbia. Report BC-R-1. 11 p.**

A thinning and nitrogen-fertilization experiment was established in a even-aged forest of Douglas-fir (*Pseudotsuga menziesii*) at Shawnigan Lake, Vancouver Island, in 1971 and replicated in 1972. This study was concerned with the treatment effects on above-ground biomass, ground cover percent, and nitrogen content of salal (*Gaultheria shallon*) and bracken fem (*Pteridium aquilinum*).

Thinning allowed more light to penetrate tree canopies and thus increased the undergrowth biomass. In contrast, fertilization increased density of tree canopies and thus decreased undergrowth ground cover and biomass. Increasing undergrowth biomass utilizes nutrients otherwise available to the trees. Heavy thinning increased biomass, and the amount of nitrogen tied up in bracken fem rose from 0.14 g/m^2 in the control to 1.06 g/m^2. The 8.4-fold increase in biomass in bracken fem produced by heavy thinning utilized 14.4 kg/ha of nitrogen. When fertilization takes place at the same time as thinning, some of the fertilizer will be tied up by the undergrowth. The above-ground parts of bracken fern contained approximately twice the nitrogen per unit dry weight as those of salal. In contrast to salal, these parts die in the fall and become litter.

Any negative effect of competition by undergrowth is assumed to be temporary in most productive stands. The beneficial effects of undergrowth on aeration of soil, retention of ground water and nutrient elements, increase of soil fauna, and prevention of erosion and leaching will probably more than make up for the nitrogen consumption. However, this study showed that the undergrowth competed with trees for nitrogen and water, and the advantages of increased water supply per tree in thinning Douglas-fir were partly offset by the water consumption of the undergrowth.

268. **STARK, N. 1980. Light burning and the nutrient value of forage. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah. Research Note INT-280. 7 p.**

Slash burning in a clearcut under conditions producing very light to light bum intensities for a short time stimulated resprouting, but essentially did not enrich biologically essential nutrients in the foliage of five herb and shrub species (wild rose [*Rosa* spp.], *Spiraea betulifolia*, heart-leaved amica [*Arnica cordifolia*], thin-leaved blueberry [*Vaccinium membranaceum*], and creeping Oregon grape [*Berberis repens*]). Bums of this low temperature range are not suitable for improving the quality and quantity of browse. Exceedingly dry soil conditions during the summer months appear to have resulted in low nutrient contents in clip plots, where plants were crowded and dense, but not in controls, where spacing was wider.

269. **STEEN, H.K. 1966. Vegetation following slash fires in one western Oregon locality. Northwest Science 40:113-120.**

Thirteen pairs of plots near Oakridge, Oregon, were examined frequently during the first 11 to 16 years after slash buming. Significantly more brush covered unburned plots than bumed plots for only the first 5 years; after 7 years, the differences in brush cover were no longer significant. Snowbrush (*Ceanothus velutinus*) and vamishleaf ceanothus (*C. velutinus* var. *laevigatus*) created dense shade on burned plots, but very little shade on unbumed plots. Much more Pacific rhododendron (*Rhododendron macrophyllum*) grew on unburned than on burned areas. Total cover of herbaceous plants was similar for both burned and unbumed plots (about 50% after 11 to 16 years), but species composition differed. American twinflower (*Linnaea borealis* var. *americana*) shaded 14 times more area on unburned than on bumed plots. Trailing blackberry (*Rubus macropetalus* [=*ursinus*]) shaded more of the burned area than the unburned. Willow-weeds (*Epilobium* spp.) were common throughout the study area and shaded burned and unburned plots equally.

270. 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.**

Foliar sprays of asulam, bromacil, dicamba, dichlobenil, or picloram were applied in May/June or July/August 1970 to western swordfern (*Polystichum munitum*) and western bracken (*Pteridium aquilinum* var. *pubescens*) in Oregon; survival was determined in September 1971. Dicamba (3 lb a.i./100 gal water) gave best control of sword-fern when applied in either spring or midsummer. In order to prevent damage to conifers, dicamba should be applied to individual ferns. In trials in western Washington, asulam (1 to 3 lb/ac a.i.) gave the most satisfactory control of bracken fern and did not affect the survival of lodgepole pine (*Pinus contorta*) or Douglas-fir (*Pseudotsuga menziesii*).

271. 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.**

Brush resprouts and seedlings increased after spraying and burning on north and south aspects in one clearcut in the Oregon Coast Range. A release spray applied 3 years after burning reduced shrub, but not herbaceous, cover. Good control of residual vegetation after logging and prompt reforestation appear to be essential in brush-threatened areas of the Coast Ranges.

272. STEWART, R.E., and T. BEEBE. 1974. **Survival of ponderosa pine seedlings following control of competing grasses. Proceedings, Western Society of Weed Science 27:55-58.**

Effects of grass control treatments on survival of newly planted ponderosa pine (*Pinus ponderosa*) were studied at five locations in Wenatchee National Forest. Six plots were installed at each site, and the following treatments were applied: (1) none - control; (2) scalp; (3) 2 lb a.e. pronamide/ac; (4) 2 lb a.e. terbacil/ac; (5) 4 lb a.e. atrazine/ac, and (6) 5 lb a.e. dalapon/ac.

Spraying with atrazine or dalapon increased pine survival 150% on sites with light-textured pumice soils and 700% on sites with heavier-textured residual soils. Scalping, pronamide, and terbacil were less effective.

273. 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.**

Aerial application of asulam at 3.4 and 6.7 kg/ha plus nonionic surfactant (0.2% solution in water) to young plantations in western Oregon effectively controlled western bracken (*Pteridium aquilinum* var. *pubescens*) without damaging seedlings of Douglas-fir (*Pseudotsuga menziesii*). Seedlings of noble fir (*Abies procera*) were damaged and their growth was reduced significantly in the year of treatment. Earlier studies showed no damage to noble fir when asulam was applied without a surfactant. The half-life of asulam in forest soils ranged from under 7 to 18 days. Vertical movement in the soil profile was minimal; no herbicide residues were found in runoff water from treated areas up to 208 days after application.

274. TERRILL, W.R. 1989. Coordinating reforestation and livestock grazing on the Tonasket Ranger District in north central Washington. P. 184-190 *In* Proceedings of the National Silviculture Workshop, 1987: Silviculture for All Resources, Sacramento, California. USDA Forest Service, Washington, D.C.

Many tree plantations in the Tonasket Ranger District have not performed satisfactorily because of competition from natural and seeded grasses, cattle trampling, and pocket gopher damage. The Silviculture Unit of the Ranger District was clearcutting and planting without regard for the grazing situation. The Range Unit was sowing grass in these clearcuts for erosion control, noxious weed control, and forage production. Several actions were taken to improve coordination between the two units, including development of a grass-seeding guide that meets acceptable range/silviculture objectives. Several categories were established in order for a grass seeding recommendation to be made. Land-management objectives were determined first: (1) erosion/weed control; (2) tree regeneration (artificial and natural); (3) forage production; (4) stabilization of roads and primary skid trails; and (5) tree stocking control. Ecological sites were classified and separated into dry and wet environments.

Tree growth and survival in dry environments probably suffer from moisture stress caused by dense grass. The presence of pinegrass (*Calamagrostis rubescens*) restricts grass seeding. Bulbous grasses are avoided where timber management is the objective, in order to reduce enhancement of pocket gopher habitat.

275. THOMAS, D.F. 1986. The use of sheep to control competing vegetation in conifer plantations on the Downieville Ranger District, Tahoe National Forest: 1981-1984. P. 89-91 *In* Weed Control for Forest Productivity in the Interior West: Symposium Proceedings, Spokane, Washington. D.M. Baumgartner, R.J. Boyd, D.W. Breuer, and D.L. Miller, eds. Washington State University Cooperative Extension, Pullman, Washington.

Grazing livestock, specifically sheep, appears to be useful for controlling competing vegetation in conifer plantations, regardless of plantation age. After four grazing seasons, sheep successfully grazed 500 ac of newly established conifer plantations, significantly reducing densities of competing vegetation without significant damage to the conifers present. The sheep grazed primarily on deerbrush (*Ceanothus integerrimus*) and greenleaf manzanita (*Arctostaphylos patula*), but they also utilized bracken fern (*Pteridium aquilinum*), orchardgrass (*Dactylis glomerata*), alfalfa, and thistle (*Cirsium* spp.).

276. THOMPSON, W.W., and F.R. GARTNER. 1971. Native forage response to clearing low quality ponderosa pine. Journal of Range Management 24:272-277.

Removal of the overstory increased forage production on forest range in South Dakota. Warm-season grasses responded more to clearing than did cool-season grasses.

277. 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.

The effects of two vegetation-management methods (paper mulching and spot-spraying with glyphosate) in combination with a root-dipping treatment (Terra Sorb®) on seedling survival and height growth were tested on a harsh site in Oregon. The site had been seeded in 1963, planted in 1974, replanted in 1977, sprayed with 2,4-D and 2,4,5-T, and sprayed with atrazine. The site was still rated as unstocked in 1981; grasses and low soil moisture had contributed to high mortality. In January 1982, bareroot 2-0 seedlings of Douglas-fir (*Pseudotsuga menziesii*) were planted.

Survival was significantly higher after the third growing season when competing vegetation had been controlled with mulch or glyphosate during the first two growing seasons. Seedlings treated again with paper mulch and glyphosate before the second growing season had 36 and 25% higher survival, respectively, than those that were not. None of the seedlings was treated again before the third season; after this season, survival of seedlings treated twice with glyphosate was 26, 23, and 21% higher than that of seedlings receiving one glyphosate treatment and one or two mulch applications, respectively. Seedling height growth did not differ among treatments. Root-dipping with Terra Sorb® did not influence survival or growth.

278. **URESK, D.W., and W.W. PAINTNER. 1985. Cattle diets in a ponderosa pine forest in the northern Black Hills. Journal of Range Management 38:440-442.**

A study of cattle diet was conducted in the northem Black Hills of South Dakota and Wyoming. Forty-eight plants were identified in cattle fecal material. Over the grazing season, an average of 54% were grasses, including smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), and big bluestem (*Andropogon gerardii*); 17% were forbs; and 28% were shrubs and trees. Sedges (*Carex* spp.) and wheatgrass (*Agropyron* spp.) were the most abundant plants found in the feces throughout the season; bur oak (*Quercus macrocarpa*), ponderosa pine (*Pinus ponderosa*), and creeping Oregon grape (*Berberis repens*) were also common. Shrubs and trees made up 37% of the diet in September. Similarities and rank order correlations of diets with available forage were low in August, indicating that cattle were grazing selectively.

279. **WAGNER, R.G., T.D. PETERSEN, D.W. ROSS, and S.R. RADOSEVICH. 1989. Competition thresholds for the survival and growth of ponderosa pine seedlings associated with woody and herbaceous vegetation. New Forests 3:151-170.**

Patterns of survival and stem-volume growth for planted seedlings of ponderosa pine (*Pinus ponderosa*) competing with various levels of woody and herbaceous vegetation were derived from two previous studies in Montana and one in Oregon. Negative hyperbolic curves of opposite concavity described the relation between the abundance of woody or herbaceous vegetation and (1) the survival and (2) the stem volume of the pine seedlings. From these curves, two types of competition thresholds for managing forest vegetation were identified: (1) maximum-response threshold - a level of vegetation abundance where additional control measures will not yield an appreciable increase in tree performance; and (2) minimum-response threshold - a level of vegetation abundance that must be reached before additional control measures will yield an appreciable increase in tree performance.

The maximum- and minimum-response thresholds for pine stem volume occurred at lower levels of vegetation abundance than those for pine survival. Thus, forest managers may need to consider ponderosa pine survival and stem-volume growth as separate objectives when managing woody and herbaceous vegetation in young plantations. Knowledge of maximum- and minimum-response thresholds also can be used to improve herbicide prescriptions.

280. **WAGNER, R.G., A.A. ROBISON, P.C. GRIESSMANN, T.B. HARRINGTON, and S.R. RADOSEVICH. 1990. VEGPRO — forest vegetation management prescription optimization and information system: a user manual. Version 1.0. Forest Research Laboratory, Oregon State University, Corvallis, Oregon. 61 p.**

VEGPRO is an interactive computer program that can assist professional foresters with selection of forest vegetation management treatments. The program can evaluate site preparation, conifer release, and individual-plant treatments for three forest vegetation types in the Pacific Northwest: (1) coastal and western Cascade deciduous woody vegetation in Oregon, Washington, and northern Califomia; (2) mixed sclerophyll woody vegetation in southwestern Oregon and northem California; and (3) herbaceous vegetation complexes in Oregon and Washington. VEGPRO can be run on any IBM-compatible computer; a hard disk drive is required.

281. WALLACE, T. 1983. Forage producing potentials in clearcut lodgepole pine types. P. 75-78 *In* Forest-land Grazing: Proceedings of a Symposium, Spokane, Washington. B.F. Roche, Jr. and D.M. Baumgartner, eds. Washington State University, Pullman, Washington.

Each year, at least 17,000 ha are clearcut in the Kamloops Forest Region, British Columbia. Since the early 1970's, a practical grass-seeding program has been pursued, with an average of 4,750 ha seeded during the last 7 years. Possibly maximum conifer development can best be obtained in the absence of grass and cattle. However, the authors found that grass sowing and subsequent livestock grazing are compatible with and, under certain circumstances, can enhance growing conditions for trees. The program will have to be greatly improved if full potential for growing trees and grass in clearcut areas is to be realized.

282. WEAVER, H. 1951. Observed effects of prescribed burning on perennial grasses in the ponderosa pine forests. Journal of Forestry 49:267-271.

From limited observations, the author concludes that properly conducted prescribed burning does not seriously damage perennial grasses in the understory of ponderosa pine (*Pinus ponderosa*). In fact, such buming appears beneficial, because it removes competing vegetation and pine-needle mats.

283. WEAVER, H. 1959. Effects of burning on range and forage values in the ponderosa pine forest. P. 212-215 *In* Proceedings, Society of American Foresters Meeting 1958, Salt Lake City, Utah. Society of American Foresters, Washington, D.C.

The grass crop appears to have deteriorated seriously over extensive portions of the ponderosa pine (*Pinus ponderosa*) forest since arrival of the white man. It has been overgrazed and is being crowded out by coniferous reproduction. Unpalatable shrubs appear to have increased at the expense of grass. Dense reproduction of ponderosa pine almost undoubtedly originated largely because of previous overgrazing, followed by exclusion of fire. Prescribed burning appeared to offer the most promising tool for correction of the undesirable conditions described.

284. WHEELER, W.P., W.C. KRUEGER, and M. VAVRA. 1980. The effect of grazing on survival and growth of trees planted in a northeast Oregon clearcut. P. 28-31 *In* Research in Rangeland Management: 1980 Progress Report, Oregon State University, Agricultural Experiment Station, Corvallis, Oregon. Special Report 586.

The objectives of this study were to determine (1) the feasibility of interim grazing of forested land from immediate postlogging to tree-canopy closure and (2) the effect of such grazing on survival and growth of planted coniferous tree stock. The authors conclude that survival and growth of planted indigenous timber species can be compatible with grazing if the following conditions are met. (1) Entry and removal of cattle must be accomplished at the proper time (i.e., proper attention must be paid to the phenological stage of both forage and tree species, and not more than 80% of the forage species should be utilized). (2) Grazing animals must be dispersed by fencing or riding and by location of water and salt. (3) Preferred forage species should be available in reasonable abundance. If preferred forage is not present, the plantation site should be bumed and seeded to adapted bunchgrasses the fall before spring planting of tree seedling stock. Tree planting should not be delayed beyond this time. (4) Competition from brush must be reduced by selective herbicides or the presence of big game animals on the plantation.

285. 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.

In April 1979, 1 month after 3-year-old Douglas-fir (*Pseudotsuga menziesii*) were transplanted, liquid and solid formulations of hexazinone were applied at 0, 1.11, 1.68, or 2.23 kg/ha to the plots, separately and in combination with glyphosate at 0 or 0.62 kg/ha. Formulations of hexazinone did not differ in effect on the herbaceous community, which was dominated by tall oatgrass (*Arrhenatherum elatius*), velvetgrass (*Holcus lanatus*), blue wild rye (*Elymus glaucus*), and trailing blackberry (*Rubus ursinus*). However, addition of glyphosate increased the mean weed-free condition from 67.25 to 85.1%. At the same time, mean height of fourth-year trees in glyphosate-treated plots was 149.9 cm, compared with 162.6 cm in hexazinone-only plots. Survival of second-year trees was also affected.

286. **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 (*Arrhenatherum elatius*), velvetgrass (*Holcus lanatus*), blue wild rye (*Elymus glaucus*), and trailing blackberry (*Rubus ursinus*). The objective was to investigate how weeds and transplants of Douglas-fir (*Pseudotsuga menziesii*) responded to liquid and solid formulations of hexazinone and whether Douglas-fir survival was increased by herbaceous weed control, even in a wetter than average summer. Growth was enhanced at least through the fourth year by hexazinone application at rates of 1.1 to 2.2 kg/ha, and all rates provided good weed control. The advantage in height growth from the hexazinone was reduced by adding glyphosate at 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.

287. **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.**

Three levels of nitrogen and four levels of hexazinone were applied to test the efficacy of the herbicide on herbaceous weeds when applied at the same time as fertilizer. The study was done on three Christmas tree plantations of Douglas-fir (*Pseudotsuga menziesii*) and noble fir (*Abies procera*) in western Oregon. Plant cover consisted of bentgrass (*Agrostis tenuis*), velvetgrass (*Holcus lanatus*), tansy ragwort (*Senecio jacobaea*), vetches (*Vicia* spp.), and scattered bracken fern (*Pteridium aquilinum*).

Forb cover responded to differences in nitrogen, but total cover, grass cover, and conifers were not affected. Increasing rates of hexazinone significantly decreased total cover and grass cover. Douglas-fir was not responsive to hexazinone rate, but increasing levels of hexazinone and corresponding decreasing levels of competition increased the percentage of healthy noble fir. Overall, incorporation of nitrazine/urea and hexazinone into cogranule prills or coliquid slurry appeared to enhance weed control significantly, relative to separate applications of the components.

288. **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.**

In order to determine if herbicide efficacy is affected by nitrogen fertilizer, the nitrogen fertilizers were applied in combination with hexazinone formulations on herbaceous weed communities. Field studies comparing three application methods in conifer plantations showed greatest reduction in total weed cover with a cogranular formulation of hexazinone and triamino-*s*-triazine. Slightly less control was achieved with separate applications of liquid hexazinone and triamino-*s*-triazine granules, and poorest control with granular urea followed by liquid hexazinone. Weed control increased with increased hexazinone rate. The highest hexazinone rate significantly increased survival of noble fir (*Abies procera*) and stem diameter of both noble fir and Douglas-fir (*Pseudotsuga menziesii*). The highest nitrogen rate significantly decreased survival of both species but did not affect stem diameter. Survival of noble fir and diameter of both noble fir and Douglas-fir were significantly increased where a cogranular formation of hexazinone and triamino-*s*-triazine granules was used.

289. WILLIAMS, G.H., and A. FOLEY. 1975. Effects of herbicides on bracken rhizome survival. Annals of Applied Biology 79:109-111.

Glyphosate sprayed on bracken (*Pteridium aquilinum*) at 1.1, 2.2, 4.5 or 6.7 kg/ha decreased the total carbohydrate content of the storage rhizome 20 months after spraying; the decrease was greater when spraying was carried out at the beginning of August, rather than at the end. Asulam, benazolin and metribuzin reduced frond numbers but showed no significant effect on the rhizomes over the same period.

290. WILLMS, W., A. McLEAN, R. RITCEY, and D.J. LOW. 1975. The diets of cattle and deer on rangeland. Canada Agriculture 20:21-23.

Studies of diet overlap on winter range of mule deer showed that competition between deer and cattle was minimal when cattle grazing was kept at recommended levels. Competition was greatest in late winter and early spring, when deer depend largely on new grass or fall regrowth to replace lost body weight and provide nourishment for fetal growth.

291. WILLMS, W., A. McLEAN, R. TUCKER, and R. RITCEY. 1980. Deer and cattle diets on summer range in British Columbia. Journal of Range Management 33:55-59.

Forage selection by mule deer and cattle was studied on summer range in the Douglas-fir (*Pseudotsuga menziesii*) zone. Both ungulates greatly preferred clover (*Trifolium* spp.), willow (*Salix* spp.), and fireweed (*Epilobium* spp.). When availability of these forages was not limiting, the percent of diet overlap was high. As their availability declined, diet overlap decreased as both deer and cattle were forced into their individual food niches: grass for cattle and shrubs for deer. Declining availability of preferred forages affected dietary composition of deer less than that of cattle. Presumably the greater selectivity of deer permitted them to utilize those forages despite reduced availability.

292. WINWARD, A.H., and D.P. RUDEEN. 1980. Sheep and deer grazing on lodgepole pine plantations. P. 22-24 *In* Research in Rangeland Management: 1980 Progress Report. Oregon State University Agricultural Experiment Station, Corvallis, Oregon. Special Report 586.

This study was designed to quantify tree damage by sheep and deer as influenced by season of grazing and forage conditions. Eight hundred seedlings of lodgepole pine (*Pinus contorta*) less than 3 feet tall were tagged and examined before and after sheep grazed the area. Only two of the tagged seedlings were browsed by sheep in 1975 and 38 in 1976. Deer browsed an average of 13.7% of the seedlings each year from 1973 through 1976. Sheep did not prefer planted to naturally regenerating seedlings. Deer, however, markedly preferred planted seedlings.

293. WOODWARD, R.A. 1987. Early changes in coast redwood (*Sequoia sempervirens*) understory vegetation following forest harvest disturbances. Ph.D. dissertation, University of California, Davis, California. 145 p.

Species composition, frequency, and cover in the understory were determined in seven redwood stands, 70 to 90 years old, that had been partially harvested since 1971. Understory cover was four times greater in tractor-logged stands harvested 10 years previously to remove 50% of the conifer basal area than in an adjacent undisturbed stand. Stands logged by cable had almost 50% more understory cover than did adjacent stands logged by tractor at the same time. Species composition and cover in the understory of tractor-logged sites with abundant soil disturbance began to resemble those of cable-logged sites about 7 years after disturbance. Forest soil moisture, evaporation, light, and temperature were sensitive to the amount of overstory canopy removed and affected the species composition in the understory. Natural regeneration by seed and stump sprouts of coast redwood, Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and hemlock (*Tsuga* spp.) was also assessed. Selective removal of grand fir and hemlock overstory suppressed seedling establishment of these species. Douglas-fir established readily from seed, especially on bare mineral soil on heavily disturbed sites. Coast redwood formed sprout clumps on most stumps, but seedling establishment was relatively poor and was positively correlated with bare mineral soil. Natural herbaceous vegetation and sword-fern (*Polystichum munitum*) were not detrimental to Douglas-fir seedling growth, but introduced herbaceous vegetation did hinder coast redwood seedling growth.

294. **YERKES, V.P. 1960. Occurrence of shrubs and herbaceous vegetation after clearcutting 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.**

A 5-year study on the H.J. Andrews Experimental Forest identified 104 species and species groups on clear-cut and slash-burned areas after removal of old-growth Douglas-fir. Of these, 101 were found in varying amounts on north slopes, whereas only 65 were found on south slopes. Species were noted as "survivors" or "invaders" according to their presence or absence under the adjacent forest canopy. Woody survivors increased slowly in frequency. Herbaceous survivors formed a relatively unimportant part of the vegetative cover. Woody invaders increased more slowly in frequency than did woody survivors. Herbaceous invaders (annuals) exhibited a high frequency the first 2 years, then declined. Herbaceous invaders (perennials) exhibited a generally rapid rise in frequency for the first 4 or 5 years, then increased more slowly. Species that were present under the forest canopy tended to be more prominent on unburned areas, whereas invading species tended to become established more rapidly on burned areas. After five growing seasons, however, species frequency on burned and unburned areas differed only slightly.

295. **YOUNG, J.A. 1965. Forage production and utilization in a mixed conifer forest in the Wallowa Mountain foothills. Ph.D. dissertation, Oregon State University, Corvallis, Oregon. 119 p.**

In this investigation, forage production and utilization of the successional vegetation of the mixed-conifer forest were characterized and evaluated on the Eastern Oregon Experiment Station Hall Ranch near Union, Oregon. The mixed-conifer forest is an assemblage of seral vegetation within the ecologic potential of a grand fir (*Abies grandis*) topo-edaphic climax. Dominance, successional trends, and the relationship of herbage and browse production to other vegetation layers in the mixed-conifer forest were determined on 141 0.01-ac macroplots, each containing four 4.8-ft^2 microplots. Forage utilization by cattle was estimated on each macroplot, and an average utilization estimate was made for each stand in the mixed-conifer forest.

Tree overstory cover was negatively associated with herbage production. The coefficient of determination of this relationship was 0.254. Overstory cover accounted for more of the variation in herbage yield than did either basal area or stems per acre.

Herbage production was about equal in sunspots, intermediate shade, and heavy shade. Sunspots were about four times as productive as heavily shaded areas, but made up only 20% of the total forest area.

A sanitation logging 2 years before the study modified the overstory cover, but may have contributed to dominance of the logged mixed-conifer stands by grand fir. This logging was both beneficial and detrimental to herbage production. Herbage production was increased where old sunspots were enlarged or new ones created, but some areas were taken out of production by heavy soil disturbance and slash accumulations. The difference in herbage production of logged and unlogged stands was highly significant when plots were selected to reduce disturbance variability.

Through facilitation of physical improvements, use of proper class of livestock, improved livestock distribution, and proper season of use, the forage resource of the mixed-conifer forest was effectively utilized by cattle. The percent of nonuse was positively related to the amount of overstory crown in the mixed-conifer forest.

296. YOUNG, J.A., J.A.B. McARTHUR, and D.W. HEDRICK. 1967. Forage utilization in a mixed-coniferous forest of northeastern Oregon. Journal of Forestry 65:391-393.

This investigation determined the relationship of the overstory crown cover to livestock utilization in a mixed-conifer forest and how this relationship was modified by the intensity of management. Livestock utilization was inversely related to overstory crown closure.

Several different types of vegetation within the forest significantly influenced utilization because of wide differences in livestock preference. Cattle preferred the blue wildrye (*Elymus glaucus*)/green lupine (*Lupinus polyphyllus*) assemblage found in the openings to the more abundant pinegrass (*Calamagrostis rubescens*) and Cusick's vetch (*Lathyrus nevadensis*) in the forest. This preference may be related to higher levels of sugars in the plants grown in the openings.

Effects of Herbaceous Vegetation on Physical and Biological Processes in Soil

297. 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.

Seedlings of Douglas-fir (*Pseudotsuga menziesii*) were grown on a site cleared of whiteleaf manzanita (*Arctostaphylos viscida*) and an adjacent cleared annual-grass meadow. Seedlings were either inoculated with pasteurized or unpasteurized soil (100-120 ml/seedling) from a nearby stand of Pacific madrone (*Arbutus menziesii*) or left uninoculated. After one growing season, whole-plant soil systems of the Douglas-fir seedlings were assayed for nitrogenase activity by the acetylene reduction method.

Acetylene reduction in rhizospheres of uninoculated seedlings from the manzanita site was significantly higher than that of uninoculated seedlings from the meadow site. Unpasteurized madrone soil increased acetylene reduction over 500% for inoculated seedlings grown on the manzanita site, but decreased it by 80% in those grown on the meadow site. The influence of madrone soil was apparently biotic; pasteurized madrone soil did not have a significant effect. No acetylene was reduced in soil without seedlings. *Azospirillum* spp., a macroaerophilic nitrogen-fixing bacterium, was isolated from within the mycorrhizae of inoculated seedlings harvested from the manzanita site.

Early successional ectomycorrhizal shrubs and hardwood trees may be important in maintaining mycorrhizal fungi and associated nitrogen fixers after severe disturbance.

298. 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.

Seedlings of Douglas-fir (*Pseudotsuga menziesii*) were planted in cleared blocks in three adjacent vegetation types in southwest Oregon: whiteleaf manzanita (*Arctostaphylos viscida*), annual-grass meadow, and an open stand of Oregon white oak (*Quercus garryana*). Within subplots in each block, either pasteurized or unpasteurized soil from a nearby stand of Pacific madrone (*Arbutus menziesii*) was transferred to the planting holes of the seedlings; control seedlings received no madrone soil.

Second-year survival averaged 92, 43, and 12% for seedlings planted on the manzanita, meadow, and oak sites, respectively. Growth differences generally paralleled survival differences. Added madrone soil, whether pasteurized or unpasteurized, did not influence survival, but growth of seedlings on the manzanita site was substantially increased by the addition of unpasteurized madrone soil. Unpasteurized madrone soil did not influence growth of seedlings in the meadow and the oak stand. Pasteurized madrone soil did not affect growth in any of the vegetation types. When added to the manzanita site, unpasteurized madrone soil nearly tripled the number of mycorrhizal root tips forming on seedlings and resulted in formation of a new mycorrhizal type not seen otherwise. As with growth, unpasteurized madrone soil had little or no effect in the other vegetation types.

Manzanita and madrone may impose a biological pattem on soils that stimulates Douglas-fir growth and survival. This study supports other reports that root symbionts and rhizosphere organisms mediate interactions among plant species.

299. **ANDERSON, E.W., and L.E. BROOKS. 1975. Reducing erosion hazard on a burned forest in Oregon by seeding. Journal of Range Management 28:394-398.**

A burned private forest was revegetated by seeding to grasses, legumes, shrubs, and trees. A field study compared results obtained on three diverse habitats. The sequence of events in carrying out this stabilization program provides a guideline for others handling similar situations; timeliness and ecological adaptation of species used are important.

Seeded grass established a satisfactory vegetational cover the first year after seeding on all three sites, whereas natural revegetation did not provide satisfactory cover on an unseeded area in 4 years. Common legumes seeded for deer forage did not survive, indicating the need for additional study of species adaptation. Broadcasting tree seed was a failure. Seeded grasses apparently suppressed development of some native shrubs, which was detrimental to wildlife habitat. Herbage production on seeded areas was about four times greater than on the unseeded area. Two years of soil loss from seeded watersheds totaled less than 5 tons/ac, as measured by the amount of sediment in debris basins.

300. **BERGLUND, E.R. 1976. Seeding to control erosion along forest roads. Oregon State University Extension Service, Corvallis, Oregon. Extension Circular 885. 19 p.**

Surface erosion from forest roads is a major management-related cause of forest stream turbidity and sedimentation. Grass and legume cover can solve surface erosion problems. Foliage protects the soil surface and reduces the impact of surface water movement. Dense root systems stabilize surface particles. Erosion can be controlled successfully with a vegetative cover of 40% or more. Controlling erosion by revegetation requires consideration of climate and soil characteristics and the physical features of plant materials in selecting species. Fertilization is often essential for establishing adequate ground cover. Refertilization every 3 to 5 years may be necessary if native vegetation does not occupy the sites. Information is included on environmental adaptability of species and on selection and seed mixture formulations for various regions in Oregon.

301. **CAMPBELL, R.E., M.B. BAKER, Jr., P.F. FFOLLIOTT, F.R. LARSON, and C.C. AVERY. 1977. Wildfire effects on a ponderosa pine ecosystem: an Arizona case study. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-191. 12 p.**

The effects of a wildfire in 1972 were evaluated on three catchment areas that were either unbumed, moderately bumed, or severely burned. Vegetation changes (overstory, herbage production, and ground cover), runoff, water quality, and various soil factors were assessed from 1972 through 1975. In the severely burned area, where about two-thirds of pine basal area was lost, infiltration rates were less and water yield increased, with accompanying soil erosion and nutrient removal. Water yields declined each year, and differences between burned areas decreased as herbaceous cover developed. Herbage production in 1974 was 1,650 lb/ac in the severely bumed area, compared with 560 lb/ac in the unburned. Deer use and rodent populations also changed.

302. **CARR, W.W. 1980. Handbook for forest roadside surface erosion control in British Columbia. British Columbia Ministry of Forests, Victoria, British Columbia. Land Management Report 4. 43 p.**

This handbook is primarily concerned with establishment of vegetation on forest road construction sites with surface erosion and sediment production. It gives specific revegetation procedures, including fertilizers and mulches to use, plant species mixtures for different sites, optimum time of application, and seeding rates.

303. **CORBETT, E.S., and L.R. GREEN. 1965. Emergency revegetation to rehabilitate burned watersheds in southern California. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Research Paper PSW-22. 14 p.**

The authors report 4-year results of revegetation measures tested for emergency erosion control after fire had denuded the San Dimas Experimental Forest in 1960. They discuss establishment of sown grasses and barley and their influence on recovery of native vegetation.

304. **CROUSE, R.P., and L.W. HILL. 1962. What's happening at San Dimas? USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California. Miscellaneous Paper 68. 4 p.**

The authors describe conditions at the San Dimas Experimental Forest in southern California, 18 months after the fire of July 1960. First-aid treatments to reduce flood and erosion damage on the steep, unstable slopes included grass sowing, check dams, terraces, and planting barley along the contours. The last treatment proved best. Grass sown aerially did not provide ground cover because of drought.

305. **CURRIE, P.O., and H.L. GARY. 1978. Grazing and logging effects on soil surface changes in central Colorado's ponderosa pine type. Journal of Soil and Water Conservation 33:176-178.**

Measurements of soil surface elevation on ponderosa pine (*Pinus ponderosa*)/bunchgrass lands in central Colorado showed that 35 years of grazing and winter logging had not caused serious erosion. All measurements indicated an aggradation of soil-surface material in relation to differences in ground cover, grazing, and timber removal. Aggradation on ungrazed areas exceeded aggradation on grazed or logged areas by less than 7 millimeters.

306. **DYRNESS, C.T. 1967. Grass-legume mixtures for roadside soil stabilization. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-71. 19 p.**

The author describes a search for legume species suitable for inclusion in grass-legume mixtures and compares the performance of several grass-legume mixtures growing in roadside slope locations.

307. **DYRNESS, C.T. 1970. Stabilization of newly constructed road backslopes by mulch and grass-legume treatments. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-123. 5 p.**

Soil loss from an unprotected newly constructed backslope was two to four times greater than loss from a comparable slope 5 years after construction. Six grass-legume and mulch treatments were tested; the two showing consistently large amounts of soil loss during the first critical rainy period were those without a straw mulch. Mulching may be essential for reducing soil loss during the first few critical months following construction.

308. GJERTSON, J.O. 1949. **Practical guides for seeding grass on skid roads, trails and landings following logging on east-side forests of Washington and Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note 49. 5 p.**

Seeding to perennial grasses effectively stabilizes soil, prevents invasion by undesirable plants, and increases forage production on ground denuded during logging. A survey in 1948 of 52 areas seeded between 1940 and 1946 found 80% of the seedings to be medium or better in success, and 45% good or very good in success. A careful check showed no evidence that these seedings decreased subsequent regeneration to ponderosa pine (*Pinus ponderosa*). Details are given on where, when, and how to seed, and species are suggested for different sites.

309. HELVEY, J.D., and W.B. FOWLER. 1979. **Grass seeding and soil erosion in a steep, logged area in northeastern Oregon. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-343. 11 p.**

This case study tested the common belief that grass seeding is needed to prevent erosion after areas are clearcut in the Blue Mountains. Changes in the soil surface height were measured at about 500 points each in a seedbed and an unseeded area on four dates spaced over 20 months. Average vertical displacement was consistently related neither to seeding nor to degree of disturbance. Variability of vertical displacement within areas treated alike was almost as great as variability between treatments.

310. JACKMAN, R.E., and N.N. STONEMAN. 1972. **Use of annual ryegrass and urea for post logging erosion control on Jackson State Forest. California Division of Forestry, Sacramento, California. State Forest Notes 48. 4 p.**

Sowing annual ryegrass (*Lolium multiflorum*) with urea (45-0-0), each applied at 50 lb/ac, provided good grass cover in disturbed areas and had become standard practice for erosion control on Jackson State Forest at the time of the study. All new road-spoil and log-landing areas were sown at the close of the logging season, usually in early October. Seed and fertilizer were broadcast with a cyclone seeder by a man walking along the berm of the road. Estimated cost was $108.01/mi of roadside ($17.31/ac x 6.24 ac/mi).

311. JACKMAN, R.E., and N.N. STONEMAN. 1973. **Roadside grassing - a post-logging practice for redwood forests. Journal of Forestry 71:90-92.**

Forest road building, landings, and skid trails expose a great deal of soil to rainfall in the first few winters after logging, until natural vegetation stabilizes the soil. Annual rye (*Lolium multiflorum*) and urea 45-0-0 provide a suitable ground cover during this period.

312. LIVINGSTON, P.L. 1977. **The reproductive biology and revegetation potential of fireweed in Alaska. M.S. thesis, University of Alaska, Fairbanks, Alaska. 60 p.**

The reproductive biology and ecology of fireweed (*Epilobium angustifolium*) in Alaska make this colonizing species a potential revegetator. Seventy-six thousand seeds were produced per shoot in open conditions; 83% of the seed germinated at 20° C. August-matured seeds are nondormant, and many germinate in the field. Seeds maturing in September appear to have a nondeep type of dormancy (some seeds germinate). Dormancy is reduced in October-dispersed seed, and dormancy is induced by environment (e.g. low temperatures). Fireweed spreads vegetatively during the growing season. Rhizome segments produced 0.1 shoots/cm under growth-chamber conditions.

Data in the literature support the hypothesis that fireweed might be used successfully in revegetation. Development of a regional revegetation technology is needed to return human-disturbed areas to plant communities of well-adapted species that stabilize soil conditions and provide lasting cover.

313. MacLAUCHLAN, R.S. 1966. Grasses and legumes for stabilizing silt producing areas in the Northwest. P. 75-84 *In* Practical Aspects of Forest Watershed Management, Symposium. Oregon State University, Corvallis, Oregon.

At the time of the report, the Soil Conservation Service (SCS) maintained three Plant Materials Centers in the Northwest, each affiliated with a state Agricultural Experiment Station. These centers assembled and tested new grasses and legumes that met the specific needs of the SCS in a particular area.

General recommendations are given for grass-legume mixtures for areas needing permanent stabilization in various forest types in the Northwest.

314. McCLURE, N.R. 1956. Grass and legume seedings on burned-over forest lands in northern Idaho and adjacent Washington. M.S. thesis, University of Idaho, Moscow, Idaho. 125 p.

A study of grass and legume seedings on burned-over forest lands was initiated in 1939. Plot seedings of about 30 grasses and legumes were made on three burned areas in northern Idaho. In the following years, additional seedings were made and the study was expanded to include northeastern Washington. Adaptability of various grasses and legumes was evaluated by observation early in the study. Quantitative data in the form of plot clippings were gathered as the study progressed. In 1955, the old seedings were inspected and data were collected wherever feasible.

Findings from eight study sites are summarized. Late fall seedings of grasses and spring seeding of legumes were most successful. Most of the grasses used in the test provided adequate ground cover for erosion control by the second growing season. Yields exceeding 1 ton/ac were obtained with some grasses on all but one study site. Highest yields were obtained the second and third growing seasons following the burn. Yield of grasses was considerably lower when stands were 10 to 15 years old. In contrast, production remained high on successful legume plots. A few legumes performed satisfactorily at two sites, but most of the legume seedings were considered failures. The success of inoculation with commercial cultures or the presence of a closely related native species appeared to be of primary importance to legume establishment and production. Grasses responded well to nitrogen fertilizers in every case. Legumes responded to applications of gypsum.

Brushy species dominated several of the sites 10 or 15 years after they were burned and seeded to grass. Grasses that provided high basal densities appeared to suppress brush most effectively. Creeping red fescue (*Festuca rubra*) was superior in this respect. Orchardgrass (*Dactylis glomerata*), tall oatgrass (*Arrhenatherum elatius*), and timothy (*Phleum pratense*) were outstanding in ability to spread by reseeding. Pubescent wheatgrass (*Agropyron thrichophorum*) and intermediate wheatgrass (*Agropyron intermedium*) spread vegetatively. Establishment of tree reproduction did not appear to be hampered on the seeded areas, compared with adjacent unseeded areas.

Yields exceeding 1 ton/ac of oven-dry forage can be obtained on most sites, and they can be maintained by applying nitrogen fertilizer. When a legume/grass mixture can be established, production may remain high for 10 to 15 years without fertilization.

315. McLEAN, A., and A.H. BAWTREE. 1971. Seeding forest rangelands in British Columbia. Canada Department of Agriculture, Ottawa, Canada. Publication 1463. 14 p.

Guidelines are provided for species selection, seedbed treatment, seeding time, and application rates for forage and erosion control seedings on southern forest ranges.

316. ORR, H.K. 1968. Soil-moisture trends after thinning and clearcutting in a second-growth ponderosa pine stand in the Black Hills. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Note RM-99. 8 p.

Thinning from 190 ft^2 basal area and nearly 2000 trees/ac of ponderosa pine (*Pinus ponderosa*) to 80 ft^2 and 435 trees apparently did not induce free water seepage to ground water in dry years when the unthinned stand did not yield seepage. Thinning reduced soil moisture depletion and hence increased the seepage potential. Clearcutting and maintenance in bare condition apparently induced free water seepage. Subsequent establishment of a weed stand, followed by Kentucky bluegrass (*Poa pratensis*), reduced seepage yield potential, but it remained higher than in thinned and unthinned portions of the stand.

317. ORR, H.K. 1970. Runoff and erosion control by seeded and native vegetation on a forest burn: Black Hills, South Dakota. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research Paper RM-60. 12 p.

Growth of seeded species and reestablishment of native vegetation reduced overland runoff and soil erosion to tolerable levels in one to four growing seasons. Gross rainfall was a poor indicator of runoff and soil erosion from small plots. Trends were best defined by declining runoff and sediment production per unit of excess rainfall. Ground-cover density (live vegetation plus litter) of 60% is postulated as the minimum necessary for soil stabilization. This cover density almost certainly could not have been reached within the 4-year study period without seeding. Seeded grasses — timothy (*Phleum pratense*) and Kentucky bluegrass (*Poa pratensis*) on coarse-textured soil, and timothy and smooth brome (*Bromus inermis*) on fine-textured soil — were especially important because of their dispersion and abundance and persistence of litter production.

318. RATLIFF, R.D., and P.M. McDONALD. 1988. Postfire grass and legume seeding: what to seed and potential impacts on reforestation. P. 111-123 *In* Proceedings, Ninth Forest Vegetation Management Conference, Redding, California. Forest Vegetation Management Conference, Redding, California.

After a wildfire on commercial forest land, the primary objective of forest managers is to protect the soil by establishing vegetation as quickly and economically as possible. Where natural seed has been reduced by high intensity fire or where erosion hazards are high, seeding herbaceous plant species may be necessary. A secondary but important objective of postfire rehabilitation through herbaceous plant seeding is to manipulate the plant community by reducing emergence and growth of shrub seedlings. However, seeded species may also compete strongly with conifers. This paper describes characteristics of grasses and legumes as they are related to erosion control and their potential to dominate conifer seedlings. The authors suggest some species for use in specific environments, with and without grazing and with regard to the time that the conifer seedlings will be planted.

319. RICE, R.M., E.S. CORBETT, and R.G. BAILEY. 1969. Soil slips related to vegetation, topography, and soil in southern California. Water Resources Research 5:647-659.

In a study at the San Dimas Experimental Forest, California, soil slips were least frequent under chaparral. They were slightly more frequent under riparian woodlands. Conversion of brush to grass may have greatly aggravated this type of erosion.

320. STONEMAN, N.N. 1971. Grass and fertilizer selection for road spoil erosion control on Jackson State Forest. California Division of Forestry, Sacramento, California. State Forest Notes 46. 9 p.

A study and demonstration of possible ways to reduce erosion from road spoil was initiated on Jackson State Forest in October 1964. Lana vetch (*Vicia dasycarpa*), annual ryegrass (*Lolium multiflorum*), and cereal barley (*Hordeum vulgare*) were tested with urea (45-0-0), superphosphate (0-20-0), and ammonium phosphate sulfate (16-0-0) fertilizers on trial plots.

The best seed/fertilizer combination was annual ryegrass fertilized with urea, each applied at 50 lb/ac. The optimum time to seed and fertilize was shortly after the first light rain in the fall. The seeded grass cover was replaced by natural vegetation in 4 to 5 years, and there was no detrimental effect on coniferous regeneration in the areas seeded to annual ryegrass.

321. **TEW, R.K. 1968. Properties of soil under aspen and herb-shrub cover. USDA Forest Service, Intermountain Forest and Range Experiment Station, Odgen, Utah. Research Note INT-78. 4 p.**

Several physical and chemical properties of soil were measured and related to site aspect and vegetation type. Soil texture, aggregation, organic matter content, nitrate production, and moisture-holding characteristics varied between aspects. Soils under aspen (*Populus tremuloides*) stands had higher organic matter content, with accompanying higher moisture-holding capacity, than did soils on adjacent herb/shrub sites.

322. **TIEDEMANN, A.R., and G.O. KLOCK. 1973. First-year vegetation after fire, reseeding, and fertilization on the Entiat Experimental Forest. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note PNW-195. 23 p.**

Vegetative cover was measured on permanent belt transects during 1971 on four watersheds that had been severely and uniformly burned in 1970 and treated as follows: seeded and fertilized with 57 kg/ha of nitrogen as ammonium sulfate; seeded and fertilized with 54 kg/ha of nitrogen as urea; seeded only; and control (no seeding, no fertilizer). Regrowth and successional pattems of native species were evaluated and success of seeding for erosion control and of fertilization with two different sources of nitrogen and one of sulfur were determined.

Seeding for erosion control improved first-year vegetative cover by up to one-third, compared to unseeded plots. Of the seeded species, orchardgrass (*Dactylis glomerata*), hard fescue (*Festuca ovina* var. *duriuscula*), and timothy (*Phleum pratense*) provided most of the first-year cover. Perennial rye (*Lolium perenne*) and yellow sweetclover (*Melilotus officinalis*) showed poor development.

Effectiveness of fertilizer in the first year was questionable, since total cover on the seeded-only watershed was nearly as great as on the watershed seeded and fertilized with ammonium sulfate, and greater than on the watershed seeded and fertilized with urea. In the early summer of 1972, however, vegetal cover on the fertilized watersheds was substantially higher than on the control or seeded-only watershed. Also, vigor of seeded species appeared to be much better on the fertilized watersheds.

323. **TIEDEMANN, A.R., and G.O. KLOCK. 1976. Development of vegetation after fire, seeding, and fertilization on the Entiat Experimental Forest. P. 171-192 *In* Proceedings, Fifteenth Tall Timbers Fire Ecology Conference, Portland, Oregon. Tall Timbers Research Station, Tallahassee, Florida.**

In order to prevent erosion and restore nutrient cycles to bumed areas in the ponderosa pine (*Pinus ponderosa*) zone, vegetative cover must be established. Seeding for erosion control has been used to encourage regrowth on these areas, as native species may be too slow. The objectives of this study were (1) to measure the rate of regrowth of native species and the pattems of succession following wildfire, (2) to determine the success of sowing a seed mix prescribed for erosion control relative to the regrowth of native vegetation, and (3) to evaluate the effects of two different sources of nitrogen and one of sulfur on regrowth of native species and growth and development of seeded species.

A mix of Latar orchardgrass (*Dactylis glomerata*), durar hard fescue (*Festuca ovina* var. *duriuscula*), Drummond timothy (*Phleum pratense*), perennial ryegrass (*Lolium perenne*), and yellow sweetclover (*Melilotus officinalis*) was spread by a fixed-wing plane. At the end of the first growing season, an average of 8.6% of the ground was covered by foliage of native and seeded species. The most salient features were the dominance of native species and the rapid development of orchardgrass. Native species retained dominance in vegetative cover during the entire 4 years of study, comprising 67 to 78% of the total vegetative cover. During the second year, vegetative cover more than doubled to 19.6%, but had reached only 22.1% by the third year. This rapid early growth probably resulted from greater than normal winter precipitation. In the fourth year, vegetative cover increased to 31.2%. Vegetative recovery was closely tied to aspect and elevation, with various species showing an affinity for different sites.

Seeded grasses comprised 22 to 33% of the total cover; thus, seeding appears to be an effective supplement to regrowth of native species. Perennial rye and yellow sweetclover performed poorly; these species probably could be deleted from the seeding mix. Seeding seems most important at higher elevations (above 3,800 ft), but seeding recommendations should be based on the prefire vegetative composition, rather than elevation or aspect. Sites with prefire composition of snowbrush (*Ceanothus velutinus*), bracken fern (*Pteridium aquilinum*), and pinegrass (*Calamagrostis rubescens*) should be low in priority for seeding.

324. **WOLLUM, A.G., II. 1962. Grass seeding as a control for roadbank erosion. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. Research Note 218. 5 p.**

In a preliminary study in western Oregon, grass sown on a steep cutting formed during road construction reduced erosion but increased surface runoff (probably owing to matting of the grass) during 3 years of observation.

325. **WOOLRIDGE, D.D. 1964. Effects of parent material and vegetation on properties related to soil erosion in central Washington. Soil Science Society of America Proceedings 28:430-432.**

In a preliminary study of physical properties of wildland soils, three soil parent materials were sampled by horizons under forest and adjacent grass cover. Soil properties analyzed were mean water-stable aggregate, bulk density, organic matter pH, total porosity, and percent clay, silt, and sand. Several of the soil properties measured were related significantly to parent material and horizon depth. Effects of vegetative cover were not reflected in overall averages of soil property values. However, when these values were classified by parent materials and horizons, forest and grass covers were associated with soil property differences, although the relation of these differences to changes in parent materials and horizons was not consistent. Over 40% of the variation in soil erosion hazard (as measured by mean size of water-stable aggregates) was accounted for by multiple variation in soil organic matter content, pH, total porosity, and bulk density.

According to this preliminary study, many significant differences in soil properties are associated with different parent materials and horizon development. There is some evidence that soil properties are differentially influenced by forest-grass vegetation, but in this study no consistent or direct relationships were established.

Appendix: Common, Product, and Chemical Names of Herbicides[1]

Common name	Product name[2]	Chemical name
2,4-D	Esteron®	(2,4-dichlorophenoxy)acetic acid
2,4-DB	Butoxone®	4-(2,4-dichlorophenoxy)butanoic acid
2,4,5-T		(2,4,5-trichlorophenoxy)acetic acid
amitrole	Amitrol-T®	1*H*-1,2,4-triazol-3-amine
asulam	Asulox®	methyl [(4-aminophenyl)sulfonyl]carbamate
atrazine	Aatrex®	6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine
benazolin	Benazalox®	4-chloro-2-oxo-3-(2*H*)-benzothiazoleacetic acid
bromacil	Hyvar®	5-bromo-6-methyl-3-(1-methylpropyl)-2,4(1*H*,3*H*)pyrimidinedione
chlorthiamid	Prefix®	2,6-dichlorothiobenzamide
clopyralid	Stinger®	3,6-dichloro-2-pyridinecarboxylic acid
cyanazine	Bladex®	2-[[4-chloro-6-(ethylamino)-1,3,5-triazin-2-yl]amino]-2-methylpropanenitrile
dalapon (2, 2-DPA)	Dalapon®	2,2-dichloropropanoic acid
dicamba	Banvel®	3,6-dichloro-2-methoxybenzoic acid
dichlobenil	Casoron®	2,6-dichlorobenzonitrile
fluridone	Sonar®	1-methyl-3-phenyl-5-[3-(trifluoromethyl)phenyl]-4(1*H*)-pyridinone
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
metribuzin	Lexone®	4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one
metsulfuron	Escort®	2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2yl)amino]carbonyl]amino]-sulfonyl]benzoic acid
norflurazon	Solicam®	4-chloro-5-(methylamino)-2-(3-(trifluoromethyl)phenyl)-3(2*H*)-pyridazinone
picloram	Tordon®	4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid
pronamide	Kerb®	3,5-dichloro-*N*-(1-dimethyl-2-propynyl)benzamide
propazine	Milogard®	6-chloro-*N,N'*-bis(1-methylethyl)-1,3,5-triazine-2,4-diamine
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
terbacil	Sinbar®	5-chloro-3-(1,1-dimethylethyl)-6-methyl-2,4(1*H*,3*H*)-pyrimidinedione
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

Author Index

(Numbers refer to abstract numbers.)

Subject Index

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