Fertilization

1. 1987. Impact of intensive forestry practices on net stand values in British Columbia. B.C. Ministry of Forests FRDA-Report 014. 109 p.

Keywords: release treatments
fertilization
thinning
yield
economics

Abstract: Yield responses to major silvicultural treatments (regeneration method, brushing and weeding, spacing and thinning and fertilizer use) are analysed in relation to growth and yield theory, and their translation into operational use of treatments to increase merchantable vol. is considered. Data from coastal Douglas fir (Pseudotsuga menziesii), western hemlock (Tsuga heterophylla) and western hemlock/Abies amabilis stands and interior white spruce (Picea glauca), lodgepole pine (Pinus contorta) and wet belt Douglas fir stands are used to quantify the net present value of treatments in terms of improvement in net stand values and merchantable vol. Potentially viable treatment options are identified for each stand type present.

OSU Link
Non-OSU Link

2. Anderson, H.W. and M. Hyatt. 1981. Feasibility of hand application of urea to forest land in western Washington. In Proceedings: Forest Fertilization Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson.pp. 205-208.

Keywords: fertilization
economics

Abstract: A large scale pilot study to determine the potential of hand fertilizing forest stands in western Washington was undertaken by the Department of Natural Resources in 1976. Tests were conducted in two major stand types of Douglas-fir (juvenile stands with voids and openings and older open growh stands), where two hand spreading techniques (broadcast and individual tree fertilization) and two types of work crews (contract and DNR) were evaluated. During the study manhours of the various job-related activities were recorded and costs determined. A total of 634 acres was treated and costs ranged from $36.95 to $125.42 per acre and averaged $81.74 per acre (1976 dollars). Costs varied because of stand type which influenced the fertilizer rate and crew type which influenced the application cost. Based on units treated in this study and assuming similar conditions, estimates of hand fertilization costs for an operational fertilization project where stand conditions would allow for a reduced fertilizer rate (individual tree fertilization) would be approximately $52 per acre at the rate of 330 pounds of urea and $42 per acre at the rate of 220 pounds of urea. This compares to costs of $61 per acre for hand broadcast application at 440 pounds of urea and $56 per acre for aerial application at the same rate. Therefore, where stand conditions allow for a reduced rate of fertilizer, hand application could be a more inviting alternative to the normal procedure of aerial application.

OSU Link
Non-OSU Link

3. Atkinson, W.A. 1981. Preliminary guidelines for fertilizing less than fully stocked stands and mixed species stands. In Conference Proceedings: Forest Fertilization
Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 59-61.

Keywords: fertilization
economics

Abstract: Foresters engaged in selecting areas for operational fertilization rarely encounter the fully stocked pure-species Douglas-fir stands that are studied by researchers. Most often the question is one of establishing minimal standards for choosing stands to fertilize. This paper offers preliminary guidelines for fertilizing less than fully stocked stands and mixed-species stands. Results are presented by age and site, and consist of a table showing minimal basal area stocking required to earn a given interest rate.

OSU Link
Non-OSU Link

4. Bailey, V.L., J.L. Smith and H. Bolton, Jr. 2002. Fungal-to-bacterial ratios in soils investigated for enhanced C sequestration. Soil-Biology-and-Biochemistry 34(7): 997-1007.

Keywords: fertilization
soil properties

Abstract: Fungi and bacteria govern most of the transformations and ensuing long-term storage of organic C in soils. We assessed the relative contributions of these two groups of organisms to the microbial biomass and activity of soils from five different ecosystems with treatments hypothesized to enhance soil C sequestration: (1) desert (an elevation gradient allowed comparison of soil developed in a cooler, wetter climate with soil developed in a warmer, drier climate), (2) restored tallgrass prairie (land reverted to native prairie in 1979 and neighbouring land farmed to row crops for ~100 year), (3,4) two forest types (Douglas fir [Pseudotsuga menziesii] and loblolly pine [Pinus taeda], unfertilized control and N-fertilized plots), and (5) agricultural land (conventional- and no-till management systems). The selective inhibition technique, using captan (fungicide) and oxytetracycline hydrochloride (bactericide), was used to determine the activities (respiration) of fungi and bacteria in each of these soils and substrate-induced respiration was used to measure total active soil microbial biomass C. Phospholipid fatty acid analysis was used to determine the composition of the soil microbial biomass and determine if the activities and structure of the microbial communities were related. Differences in fungal-to-bacterial (F:B) activities between treatments at a site were greatest at the prairie sites. The restored prairie had the highest F:B (13.5) and high total C (49.9 g C kg-1 soil); neighbouring soil farmed to maize had an F:B of 0.85 and total C of 36.0 g C kg-1 soil. Within the pairs of study soils, those that were tilled had lower fungal activities and stored C than those that were managed to native or no-till systems. In all pairs of soils, soils that had higher absolute fungal activities also had more total soil C and when two extreme cases were removed fungal activity was correlated with total soil C (R2=0.85). Thus, in this small set of diverse soils, increased fungal activities, more than F:B ratios, were associated with increased soil C.

Practices that involved invasive land management decreased fungal activity and stored soil C compared to similar soils that were less intrusively managed.

OSU Link
Non-OSU Link

5. Ballard, T.M. 1984. A simple model for predicting stand volume growth response to fertilizer application. Canadian-Journal-of-Forest-Research 14(5): 661-665.

Keywords: fertilization
growth

Abstract: The equation R=KTACZQ is used to predict cumulative stand volume growth response (R) to fertilizer application, where K is a constant and the last 5 (dimensionless) multipliers represent functions of time, amount of fertilizer applied, stand composition, stocking, and site quality, respectively. Site-specific input data requirements are stand composition expressed as percent responding species, stocking expressed as a percentage of normal stocking, and site index. The model was calibrated for Douglas-fir response to nitrogen using data from Washington and Oregon. A preliminary test of the model and its calibration compared predicted responses with estimates of actual response derived from some fertilizer trials on Vancouver Island. Soil drainage class and foliar analysis data may help in qualitatively inferring whether the model's site quality function leads to overestimation of response. Future development of the model may include development and calibration of a predictively better site quality function which quantitatively uses site water regime and stand nutrient data.

OSU Link
Non-OSU Link

6. Ballard, T.M. and N. Majid. 1985. Use of pretreatment increment data in evaluating tree growth response to fertilization. Canadian-Journal-of-Forest-Research 15(1): 18-22.

Keywords: fertilization
growth

Abstract: The use of pretreatment increment can lead to improved estimates of individual and average tree growth response to fertilizing, by helping to adjust for site as well as stand structure differences between fertilized and control areas. It has applications in research using either single-tree or plot fertilizing, and also in estimating responses to operational fertilizing. Equations for analysing increment response to fertilizing are presented and discussed and 2 particularly useful ones were evaluated by examining branch length increment data from foliar spray application of iron and copper to Pinus contorta and of nitrogen and iron to Pseudotsuga menziesii, in field trials in British Columbia.

OSU Link
Non-OSU Link

7. Barclay, H., H. Brix and C.R. Layton. 1982. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 9 year growth response. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-238. 35 p.

Keywords: fertilization
thinning
growth

Abstract: Further results are given for a trial established in 1970 in a 24-yr-old stand in British Columbia, last measured 6 yr after treatment. Volume increments over 9 yr for heavy thinning alone, heavy fertilizer (urea) treatment alone, or both together, were 46%, 75% and 120%, respectively.

OSU Link
Non-OSU Link

8. Barclay, H.J. and H. Brix. 1984. Effects of urea and ammonium nitrate fertilizer on growth of a young thinned and unthinned Douglas-fir stand. Canadian-Journal-of-Forest-Research 14(6): 952-955.

Keywords: fertilization
thinning
growth
tree physiology
tree/stand health

Abstract: The effects were studied of 2 sources of nitrogen fertilizer applied at rates of 224 and 448 kg/ha N on growth of thinned and unthinned plots established in 1970 in a 24-yr-old stand on southern Vancouver Is., British Columbia. Ammonium nitrate yielded higher growth of diam. and vol. than urea over a 9-yr period, particularly with thinning. Ht. growth was not affected by nitrogen source. The efficiency of nitrogen fertilizing in terms of stem vol. response per kilogram of nitrogen applied was greatest with ammonium nitrate in thinned plots. Tree mortality increased substantially with fertilizing for both sources, and decreased markedly with thinning.

OSU Link
Non-OSU Link

9. Barclay, H.J. and H. Brix. 1985a. Effects of high levels of fertilization with urea on growth of thinned and unthinned Douglas-fir stands. Canadian-Journal-of-Forest-Research 15(4): 730-733.

Keywords: fertilization
thinning
growth
tree physiology
tree/stand health

Abstract: Diameter height and volume growth were documented for 9 yr after thinning and fertilizing in a 24-yr-old stand on a poor site on southern Vancouver Is. The treatments involved 3 thinning treatments (0, 1/3, and 2/3 b.a. removed) and 6 fertilizer treatments (0-1344 kg/ha N) with urea. Increments for both diameter and gross volume increased with the rate of fertilizer application and responses were still apparent 9 yr after treatment. For unthinned plots, the 9-yr volume growth responses were 30, 50, and 80% with fertilizer rates of 224, 448, and 896 kg/ha N, respectively. The efficiency of fertilizer use, measured as stem volume response per unit of nitrogen applied, decreased

with rate of fertilizer application, but this result may change over a longer response period. There was a positive interaction between fertilizing and thinning such that high amounts of both mutually enhanced growth. Mortality increased with fertilizing, but only noticeably in unthinned plots.

OSU Link
Non-OSU Link

10. Barclay, H.J. and H. Brix. 1985b. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 12-year growth response. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-271. 34 p.

Keywords: fertilization
thinning
growth

Abstract: [See FA 45, 2316] Further results are given from the study established in 1970 in a 24-yr-old stand in British Columbia. Fertilizers (urea) and thinning both increased vol. increments over 12 yr. Refertilization 9 yr after initial treatment has produced substantial increases in vol. increment.

OSU Link
Non-OSU Link

11. Barclay, H.J. and C.R. Layton. 1990. Growth and mortality in managed Douglas fir: relation to a competition index. Forest-Ecology-and-Management 36(2-4): 187-204.

Keywords: fertilization
thinning
growth
tree/stand health

Abstract: Twelve-year increments of diameter at breast height (DBH), height, and volume in thinned and fertilized 45-year-old Douglas fir (Pseudotsuga menziesii) stands on Vancouver Island, Canada, were related (by regression) to degree of thinning, amount of fertilizer (3x3 factorial), initial DBH, and a competitive stress index (CSI). The ability of the CSI to predict growth after treatment was examined. Causes of tree death, and CSI data, are presented, and the relationship between them discussed. The CSI was found to be only moderately good at predicting Douglas fir growth and mortality: initial DBH provided a better predictor. Most mortality in unthinned plots resulted from suppression, and correlated reasonably well with CSI; mortality in thinned plots was not correlated with CSI, and resulted principally from snow damage. Tree height variability generally became less over the 12 years following treatment, which is more consistent with two-sided than one-sided competition predictions, a result which is contrasted to that of many other species.

OSU Link
Non-OSU Link

12. Barclay, H.J., P.C. Pang and D.F.W. Pollard. 1986. Aboveground biomass distribution within trees and stands in thinned and fertilized Douglas-fir. Canadian-Journal-of-Forest-Research 16(3): 438-442.

Keywords: fertilization
thinning
carbon allocation

Abstract: Nine years after heavy thinning and fertilization with urea, 34-yr-old Douglas firs at Shawnigan Lake (British Columbia) were destructively sampled. Dry wt. of seven aboveground components (wood, bark, dead branches, new or old foliage, new twigs and live branches) were determined and regression equations from d.b.h. were developed. Differences among treatments were shown for all biomass components and for the proportion of the total biomass allocated to each component. Thinning reduced the proportion of wood, bark and dead branches while increasing the proportion of foliage and live branches. Fertilization increased the proportion of branches but had negligible effects on the proportions of other components.

OSU Link
Non-OSU Link

13. Barclay, H.J. and J.A. Trofymow. 2000. Relationship of readings from the LI-COR canopy analyzer to total one-sided leaf area index and stand structure in immature Douglas-fir. Forest-Ecology-and-Management 132(2/3): 121-126.

Keywords: fertilization
thinning
tree morphology

Abstract: Estimation of leaf area is important in predicting potential growth. This estimation is often done by means of a photometer, such as the LI-COR plant canopy analyser, but such instruments generally give biased estimates. Consequently, conversion factors are required to convert output from the photometer to the actual leaf area index (LAI). Foliar biomass was estimated in a 52-year-old Douglas fir (Pseudotsuga menziesii) stand at Shawnigan in British Columbia, Canada, which had been treated with 3 levels of thinning and 3 levels of fertilizer 28 years previously. The 4 treatment extremes (no thinning or fertilizing, no thinning and heavy fertilizing (448 kg N/ha as urea), heavy thinning (to 1/3 basal area) and no fertilizing, and heavy thinning and heavy fertilizing) were sampled for foliage. Projected leaf areas were calculated from these biomass samples using specific leaf areas derived in a previous biomass sampling. Total one-sided leaf area was then computed by dividing the projected leaf areas by 0.9 to allow for lateral leaf curvature. In addition, LAI-2000 readings were taken in the same plots and then factors were derived to convert LAI-2000 readings to total one-sided LAI. These conversion factors were found to vary strongly with quadratic mean diameter, stand density, mean diameter at breast height, mean height and stand basal area. The effect of live crown height was minimal. These should allow the prediction of the conversion factor based on 2 or 3 of these highly correlated factors.

OSU Link
Non-OSU Link

14. Bare, B.B. 1981. Tax effects of fertilization. In Proceedings: Forest Fertilization Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 238-242.

Keywords: fertilization
economics

Abstract: This paper describes the sensitivity of investment performance when fertilzization activities are treated as expensed, capitalized, or amortized expenditures. Current Internal Revenue Service policy favors capitalization, but pending revenue rulings are expected to recommend amortization. The impact of these three alternatives on after-tax cash flows is illustrated by a numerical example for the Douglas-fir zone of the USA.

OSU Link
Non-OSU Link

15. Binkley, D. and P. Reid. 1984. Long-term responses of stem growth and leaf area to thinning and fertilization in a Douglas-fir plantation. Canadian-Journal-of-Forest-Research 14(5): 656-660.

Keywords: fertilization
thinning
tree morphology
carbon allocation
growth

Abstract: Replicated thinning and nitrogen fertilization plots in a 53-year-old plantation in Washington State were examined for repsonses in stem growth, leaf area, and stem growth per unit leaf area. Although measurements occurred 20-30 yr after plot installation, substantial effects from the various treatments were still present. Thinning reduced leaf area of the stands but increased stem growth per unit leaf area, resulting in little difference in stem growth per ha over the 5-yr measurement period (1977-81). Fertilization increased both stand leaf area and stem growth per unit leaf area, and more than doubled 5-yr stem growth per ha. Consideration of the role of leaf area and stem growth per unit leaf area in determining stand treatment responses may account for much of the variation found among replicates of treatments or between studies on different sites.

OSU Link
Non-OSU Link

16. Binkley, D. and P. Reid. 1985. Long-term increase of nitrogen availability from fertilization of Douglas-fir. Canadian-Journal-of-Forest-Research 15(4): 723-724.

Keywords: fertilization
growth
tree physiology
soil properties

Abstract: [See FA 44, 4708; 46, 1837] Most Douglas-fir stands respond to nitrogen fertilizing by increasing stem growth for less than 8 yr, but one plantation at the United States Forest Service Wind River Experimental Forest in Washington State has responded for over 15 yr. In this study nitrogen concn. of foliage and fresh litter were shown to be higher in the fertilized plots (470 kg/ha N) 18 yr after fertilizing. Retranslocation of N from senescent needles was not affected and stem growth per unit N in

the canopy was similar between unfertilized and fertilized plots. An index of soil N availability in the fertilized plots was twice that of unfertilized plots. The higher stem growth, leaf area, and stem growth per unit leaf area demonstrated in an earlier study appeared to be related to a sustained increase in soil N availability rather than increased N-use efficiency. An examination of soil N transformation processes is needed to complete the explanation of the unusually prolonged fertilizer response in these plots.

OSU Link
Non-OSU Link

17. Blake, J., S.R. Webster and S.P. Gessel. 1988a. Soil sulfate-sulfur and growth responses of nitrogen-fertilized Douglas-fir to sulfur. Soil-Science-Society-of-America-Journal 52(4): 1141-1147.

Keywords: fertilization
soil properties
growth

Abstract: Two studies were conducted to determine the growth response of N-fertilized Douglas fir [Pseudotsuga menziesii (Mirb.) Franco] to S supplements. The relationship between response and soil SO4-S extracted with Morgan's solution, 1.22 M NaOAc + 0.53 M HOAc (pH 4.8), was used to establish critical levels for S. Douglas fir seedlings were grown in the greenhouse in the surface mineral layer (0 to 0.15 m) of 20 forest soils from western Washington and Oregon. On the average, significant increases in total dry weight (17.5%), stem diameter (10.1%), and height (6.9%) occurred when soils were fertilized with N and S in comparison to N alone. Using the Cate-Nelson procedure, growth responses to N and S were most likely to occur when soil SO4-S was below 14 mg S kg-1. Twenty eight installations were established in the field containing five treatments, three rates of N as urea, and one plot of 336 kg N ha-1 with P, K, Ca, and S. Differences in percent basal area growth between N alone and N with P, K, Ca, and S were significantly related to soil SO4-S. Over the initial 5-yr period, response over N alone was improved by 74% when soil SO4-S was <20 mg S kg-1. When the N with P, K, Ca, and S plots were retreated with only N and S, response over the next 3 yr was more than doubled compared with N alone. Identification of S responsive stands was improved by the inclusion of stand age weighted subsoil SO4-S concentrations.

OSU Link
Non-OSU Link

18. Blake, J.I., H.N. Chappell, W.S. Bennett, S.R. Webster and S.P. Gessel. 1990. Douglas fir growth and foliar nutrient responses to nitrogen and sulfur fertilization. Soil-Science-Society-of-America-Journal 54(1): 257-262.

Keywords: fertilization
tree physiology
growth

Abstract: Nitrogen-fertilizer response in conifer stands of the Pacific Northwest has been related to soil and foliar S, and growth has sometimes been enhanced by the addition of S. Five stands of Douglas fir (Pseudotsuga menziesii) in Washington or Oregon, with low to moderate quantities of sulfate in the mineral soil horizon, were treated with N (urea) alone or with S (as ammonium sulfate). The results

indicated that levels of soil sulfate did not provide local or site-specific predictions of the magnitude of the gain from applying N with S. The observed treatment effects were highly variable. Foliar N concentrations in the N plus S treatment were generally higher than in the N treatment. Little change in foliar S content occurred in the N plus S plot. Periodic annual growth response to N over the study period was inversely related to site index and directly related to foliar N content.

OSU Link
Non-OSU Link

19. Bodner, J. 1984. Effect of thinning and fertilization on wood properties and intra-ring characteristics in young Douglas-fir. Holzforschung-und-Holzverwertung 36(1): 5-11.

Keywords: fertilization
thinning
wood quality

Abstract: Studies were made on samples from a total of 21 trees (felled in 1982) from 42-yr-old control and thinned/[N] fertilizer-treated stands near Sweet Home, Oregon, and a 48-yr-old thinned stand near Corvallis. Wood properties, studied between and within treatments, included ring density (analysed by X-ray densitometry), earlywood and latewood density, min. earlywood density, max. latewood density, and ring width. There was n.s.d. in av. wood density between treatments. There were significant between-treatment differences in MOE and MOR. Heavy thinning (during the juvenile wood formation phase) reduced latewood fibre length by 26.5%. Min. earlywood density and max. latewood density were the most important components of ring density.

OSU Link
Non-OSU Link

20. Briggs, D.G., F. Mecifi and W.R. Smith. 1986. Effect of sludge on wood properties: a conceptual review with results from a sixty-year-old Douglas-fir stand. *In* The forest alternative for treatment and utilization of municipal and industrial wastes. *Ed.* D.W. Cole, C.L. Henry, and W.L. Nutter. Seattle, Washington, USA: University of Washington Press. pp. 246-257.

Keywords: fertilization
wood quality

Abstract: Expected changes in wood properties due to cultural practices are reviewed. The hormone theory and published studies on the effects of thinnings and fertilizers are used to provide a basis for hypotheses describing the effects of sludge treatments on wood properties. Notes are given on the effect of municipal sludge on relative density, tracheid characteristics and strength properties of Douglas fir.

OSU Link
Non-OSU Link

21. Brix, H. 1984. Effects of thinning and nitrogen fertilization on growth of Douglas-fir: relative contribution of foliage quantity and efficiency. Canadian-Journal-of-Forest-Research 13(1): 167-175.

Keywords: fertilization
thinning
growth
carbon allocation
tree morphology

Abstract: [See FA 43, 1948, 3839] On Vancouver Island, aboveground biomass and annual production over 7 yr was studied in relation to thinning and nitrogen fertilization at 24 yr old. Biomass yield of both treatments increased during the first 3-4 yr then decreased for fertilization but not with thinning. Treatments doubled biomass production of individual trees over the study period when applied separately and quadrupled it when combined. Annual biomass production per unit of foliage (E) increased during the first 3-4 yr, but was at or below control level after 7 yr. E accounted for 20, 37, and 27% of the stemwood dry matter response to thinning, fertilization and the combined treatments, respectively; the remainder was attributed to an increase in foliage biomass. Thinning, but not fertilization, influenced distribution of radial growth along the stem, increasing growth only below the top one-third of the stem. This pattern was related to crown development.

OSU Link
Non-OSU Link

22. Brix, H. 1993. Fertilization and thinning effect on a Douglas-fir ecosystem at Shawnigan Lake: a synthesis of project results. B.C. Ministry of Forests FRDA-Report 196. X + 64 p.

Keywords: fertilization
thinning
growth
tree morphology
tree/stand health
carbon allocation
wood quality
tree physiology
photosynthesis
economics

Abstract: Treatments were initiated in 1970-71 in a 24-year-old Douglas fir (Pseudotsuga menziesii) near Shawnigan Lake, Vancouver Island, British Columbia, to determine the effects of 3 intensities of thinning (removing none, one-third and two-thirds of basal area) and 3 levels of urea fertilizer (0, 224 and 448 kg N/ha) on the growth and biology of the trees. Subsidiary experiments were established during 1972-87 to examine the effects of high doses of urea (672-1344 kg N/ha), ammonium nitrate as an N source instead of urea, understorey response to thinning and fertilizer, and responses to P and S fertilizer.

OSU Link
Non-OSU Link

23. Brix, H. and A.K. Mitchell. 1983. Thinning and nitrogen fertilization effects on sapwood development and relationships of foliage quantity to sapwood area and basal area in Douglas-fir. Canadian-Journal-of-Forest-Research 13(3): 384-389.

Keywords: fertilization
thinning
tree morphology
tree physiology

Abstract: A 24-yr-old stand in British Columbia was treated in 1971-72 with various intensities and combinations of N fertilization and thinning. For 5-9 yr after treatments, trees were sampled to determine effects on foliage quantity and sapwood characteristics at varying stem ht. together with their relationships. Sapwood width remained relatively constant up the stem where heartwood was present, but the number of annual rings it contained decreased with ht. The sapwood width at b.h. increased with stem diam.; treatments had little effect on % sapwood at b.h. The ratio of foliage mass to sapwood cross-sectional area changed for different portions of the crown and was lower when based on sapwood area at b.h. than at base of live crown. Significant linear relationships of foliage mass and area to sapwood area at b.h. were found, but relationships of foliage to b.a. were just as close for all treatments; treatments significantly affected these relationships with control trees having the lowest regression slopes.

OSU Link
Non-OSU Link

24. Brix, H. and A.K. Mitchell. 1986. Thinning and nitrogen fertilization effects on soil and tree water stress in a Douglas-fir stand. Canadian-Journal-of-Forest-Research 16(6): 1334-1338.

Keywords: thinning
fertilization
soil properties
tree physiology

Abstract: Soil and tree water potentials were studied for 10 yr in a Douglas fir stand near Shawnigan Lake, British Columbia that was treated when 24 yr old with heavy thinning (removing superscript 2/3 of b.a.) and/or fertilization with 448 kg N/ha as urea. Control plots were not thinned or fertilized. Throughout the 10 yr, thinning increased soil water potential during the dry summer periods (July-early Oct.) by as much as 1 MPa. The effect of fertilization on soil water potential was slight and nonsignificant, and only apparent towards the end of the study in spite of large increases in leaf area (50% after 7 yr). Fertilization increased water use efficiency. The favourable soil water conditions produced by thinning led to improved shoot water potential only during predawn and early morning. Removal of understorey in a thinned and fertilized plot did not affect soil or shoot water potential.

OSU Link
Non-OSU Link

25. Carr, W.W. 1987. Restoring productivity on degraded forest soils: two case studies. B.C. Ministry of Forests FRDA-Report 002. vi + 21 p.

Keywords: site preparation
fertilization
tree physiology

growth
soil properties

Abstract: The use of green fallowing was studied at 2 sites, viz. (a) a coastal site at Koksilah, 15 km NW of Shawnigan Lake, British Columbia, where extensive subsoil exposure had resulted from roading operations in a highly productive Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) stand, and (b) an inland site 30 km S. of Vanderhook including several landings and skid roads which had been deep-ripped to a depth of 50 cm, reducing soil density to 1350 kg/msuperscript 3. Plots at (a) were seeded in 1976 at 100 kg/ha with a grass/legume mixture including 3 spp. of Trifolium and Lotus corniculatus, and received NPK (10:30:10) at 450 kg/ha. Site nutrient levels improved substantially over 5 yr with N showing the greatest gains, and Douglas fir seedlings (1+2) planted in 1977 responded with increased foliar N and K contents and 300% greater ht. growth. Plots at (b) were seeded in 1981 at 40 kg/ha with a legume mixture of 3 spp. of Trifolium, Medicago sativa and L. corniculatus, and received NPK (19:19:19) at 300 kg/ha. Nutrient gains were found after 2 yr for P, K and especially N, and although foliar nutrient contents and growth of lodgepole pine (Pinus contorta) seedlings showed no increase, the enhancement of site nutrient capital is considered to be a gain likely to benefit commercial forestry production.

26. Carter, R. and K. Klinka. 1992. Use of ecological site classification in the prediction of forest productivity and response to fertilisation. South-African-Forestry-Journal (160): 19-23.

Keywords: fertilization
growth
soil properties

Abstract: The results are presented of two related studies in southern coastal British Columbia. A total of 149 study plots in even-aged immature Douglas fir (Pseudotsuga menziesii) stands were categorized into 6 ecologically similar site associations (indicated best by climax plant communities) and into 15 soil moisture and soil nutrient combinations, for the prediction of site index. Fifty-one of these plots were used to predict basal area growth response to nitrogen fertilizer (225 kg N/ha as urea). Regression models indicated strong correlations between Douglas fir site index (m (height)/50 yr) and both indirect and direct measures of soil moisture and nutrient regimes (Rsuperscript 2 >0.72; p <0.01). Third-year basal area response to N fertilizer varied significantly among site associations (Rsuperscript 2 = 0.60; p <0.01). Site index also showed a significant relation with third-year basal area response (Rsuperscript 2 = 0.52; p <0.01), while the best predictive model included site associations and pretreatment foliar N and sulfate-S (Rsuperscript 2 = 0.64; p <0.01). It is suggested that the approach and methods of the study are applicable to predicting site-specific growth performance and response to fertilization of other tree species, including eucalypts.

27. Carter, R. and R. Scagel. 1989. The effects of stand density and fertilization on stand development in immature coastal Douglas-fir. B.C. Ministry of Forests FRDA-Report 094. i + 15 p.

Keywords: fertilization
thinning
growth
tree morphology

Abstract: The effects of urea fertilizer were studied in Pseudotsuga menziesii stands spaced to 500, 750 and 1000 stems/ha in coastal British Columbia.

OSU Link
Non-OSU Link

28. Carter, R.E. and R.P. Brockley. 1990. Boron deficiencies in British Columbia: diagnosis and treatment evaluation. Forest-Ecology-and-Management 37(1-3): 83-94.

Keywords: fertilization
growth
tree/stand health

Abstract: Two case-studies are presented, outlining methods of diagnosis and treatment evaluation of boron deficiencies in a Douglas fir (Pseudotsuga menziesii) stand in coastal southern British Columbia and a lodgepole pine (Pinus contorta) stand near Burns Lake, in the interior of the province. Site conditions commonly associated with B deficiency are outlined, and relations between dormant-season foliar B concentration and growing-season precipitation and moisture stress are suggested. Diagnostic methods used in the study include examination of deficiency symptoms, and foliar-analysis techniques; evaluation of response for corrective fertilizer treatments is based on changes in frequency and severity of deficiency symptoms and growth responses, measured by graphical-analysis and changes in shoot length between treatments. Boron deficiencies and response to B fertilizers are difficult to confirm. Results of graphical-analysis and examination of frequency and severity of deficiency symptoms were inconclusive, while changes in shoot length identified a measurable response in the Burns Lake fertilizer trial with lodgepole pine. Deficiencies appear to be acute rather than chronic, and may not occur in untreated control trees for several years after establishment of fertilizer trials. Alternative causes for deficiency symptoms are also common, further complicating diagnosis and evaluation of response to treatment. It is concluded that all future trials should include nitrogen and/or other limiting nutrients with and without B to aid in identification of acute B deficiencies and deficiencies induced by increasing growth.

OSU Link
Non-OSU Link

29. Carter, R.E., E.R.G. McWilliams and K. Klinka. 1998. Predicting response of coastal Douglas-fir to fertilizer treatments. Forest-Ecology-and-Management 107(1/3): 275-289.

Keywords: fertilization
growth
soil properties

Abstract: A broadly-based, intensive Douglas-fir (Pseudotsuga menziesii) fertilizer experiment throughout southern coastal British Columbia (48 sites) was used to examine 3- and 6-yr crop tree growth responses to prescribed fertilizer applications (N alone, and N + additional nutrients identified as potentially deficient by foliar analysis). Absolute and relative basal area responses were evaluated in relation to site associations of the provincial ecosystem classification system, site index (SI), and a large number of site and stand chemical and physical properties. Few of the site and stand variables examined as possible response prediction criteria appeared to have any real utility. The strongest relationships found were between relative basal area response and (1) site index (Rsuperscript 2 0.46 for both 3- and 6-yr responses), (2) mineral soil mineralizable-N (Rsuperscript 2 0.50 and 0.46 for yr 3 and 6 responses, respectively), and (3) total mineralizable-N (Rsuperscript 2 0.47 and 0.50 for yr 3 and 6 responses, respectively). In all cases average relative response declined with increasing site quality. However, there were highly productive sites (SI50 <more or =>35 m) characterized by an absence of growing-season water deficits and relatively low foliar N concentrations (12-13 g/kg) which showed significant fertilizer responses. These sites are where the greatest financial returns from fertilizing may be realized. Relationships identified between site and stand variables and basal area responses were, in many cases, different from those found by other researchers for coastal Douglas fir. This brings the portability of identified relationships into question.

OSU Link
Non-OSU Link

30. Chapman, R.J. 1984. Growth, nitrogen content and water relations of sludge-treated Douglas-fir seedlings. Forestry-Abstracts 45(7): 385-386.

Keywords: fertilization
growth
tree physiology

OSU Link
Non-OSU Link

31. Chappell, H.N., D.W. Cole, S.P. Gessel and R.B. Walker. 1991. Forest fertilization research and practice in the Pacific Northwest. Fertilizer-Research 27(1): 129-140.

Keywords: fertilization
soil properties

Abstract: A review showed that most Pacific Northwest USA Douglas-fir (Pseudotsuga menziesii) forest sites are nitrogen deficient. Mineral cycling research has shown high C:N ratios and low nitrification rates for soils in the region. Research and development projects in the Pacific Northwest have produced an information base that is used to select sites and stands for fertilization and to forecast growth after treatment. Much of the basis for operational fertilization programmes in western Oregon and Washington comes from cooperative research; current activities for these programmes are directed toward improving site-specific response information. Forest fertilization in the Pacific Northwest has become a major silvicultural practice over the past two decades. Forest industry and government organizations managing forest lands in western Oregon and Washington apply nitrogen fertilizer to Douglas-fir stands over a range of soil and stand types. About 50 000 to 55 000 ha are fertilized each year, and future programmes will probably be

of similar magnitude. Most current plans for management regimes including fertilization require multiple applications.

OSU Link
Non-OSU Link

32. Chappell, H.N., C.E. Prescott and L. Vesterdal. 1999. Long-term effects of nitrogen fertilization on nitrogen availability in coastal Douglas-fir forest floors. Soil-Science-Society-of-America-Journal 63(5): 1448-1454.

Keywords: fertilization
soil properties

Abstract: The aim of this study was to determine if N availability was elevated 8 to 12 years after repeated N fertilization, and if the effects of N fertilization were related to the soil N capital. Rates of N cycling in control and fertilized plots of Douglas-fir (Pseudotsuga menziesii) in Oregon, USA, were compared by measuring net N mineralization rates in forest floors and by estimating rates of N turnover from the litterfall/forest floor ratio. Litterfall N contents, litter N concentrations, and rates of N turnover increased along the gradient in soil N capital in both control and fertilized stands. Fertilization did not affect litterfall N content, but C:N ratios of litter and forest floors were significantly lower in fertilized stands along the gradient. Turnover rates of N in the forest floors were not higher in fertilized plots than in control plots, nor were rates of net N mineralization affected by fertilization. Net nitrification rates were higher in some of the plots that received 1120 kg N ha-1 than in control plots. Nitrogen fertilization did not result in a sustained increase in N cycling and N availability analogous to a higher site N capital, and the effect of N fertilization was not related to the initial soil N capital of these sites.

OSU Link
Non-OSU Link

33. Cochran, P.H., W. Lopushinsky and P.D. McColley. 1986. Effect of operational fertilization on foliar nutrient content and growth of young Douglas-fir and Pacific silver fir. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Note PNW-RN-445. 10 p.

Keywords: fertilization
tree physiology
growth

Abstract: During 1979-80, sulfated urea (pelletted) was applied to conifer stands in the Wenatchee National Forest, west of Cle Elum, Washington. Nitrogen concn. in current needles of Pacific silver fir (Abies amabilis) showed a significant 1.9-fold increase after fertilizer treatment compared with a non-significant 1.3-fold increase in Douglas fir (Pseudotsuga menziesii). A significant 2.5-fold increase in foliar N also occurred in bracken (Pteridium aquilinum). Analysis of foliage from untreated trees indicated N deficiency in A. amabilis, but N concn. in Douglas fir was above threshold values. Fertilizer treatment did not affect foliar S in either species, but increased needle surface area for A. amabilis. Tree diam. growth, stand b.a. growth and vol. growth were all increased by fertilizer treatment.

OSU Link
Non-OSU Link

34. Cole, D.W., M.L. Rinehart, D.G. Briggs, C.L. Henry and F. Mecifi. 1984. Response of Douglas fir to sludge application: volume growth and specific gravity. *In* Proceedings of the Technical Association of the Pulp and Paper Industry 1984 Research and Development Conference, Appleton, Wisconsin, September 30-October 3. pp. 77-84.

Keywords: fertilization
thinning
growth
wood quality

Abstract: In 1977 and 1980 municipal sludge was applied to a 60-yr-old lowland Douglas fir stand in Washington State. Application procedures and rates and suitable sites for treatment are described. There was a 6 yr av. diam. growth response of 93% in unthinned and 48% in thinned stands treated with 142 t/ha sludge and a vol. growth response of 53 and 42%, respectively. The accelerated rate of growth has not shown signs of decreasing since treatment. Relative density of sludge-grown wood was 10-15% less than that of untreated wood, but within the range for Douglas fir grown on higher land. This is thought to be a result of the change in forest site produced by the sludge treatment.

OSU Link
Non-OSU Link

35. Colinas, C., R. Molina, J. Trappe and D. Perry. 1994a. Ectomycorrhizas and rhizosphere microorganisms of seedlings of Pseudotsuga menziesii (Mirb.) Franco planted on a degraded site and inoculated with forest soils pretreated with selective biocides. New-Phytologist 127(3): 529-537.

Keywords: planting operations
fertilization
soil properties
mycorrhizal response

Abstract: Inoculation of planting holes with small amounts of soil from a mature forest or a plantation can improve formation of ectomycorrhizas on Pseudotsuga menziesii seedlings in degraded clearcuts in southwestern Oregon. To determine the component(s) of transferred soil responsible for increased ectomycorrhiza formation, soil from a clearcut, a mature forest and a plantation was treated with one of the following: (1) fertilizer to test for the effect of nutrients, (2) dimethoate and carbofuran to test for the effect on microarthropods or nematodes, (3) fumagillin to test for the effect on protozoa, (4) captan to test for the effect on fungi, (5) penicillin and oxytetracycline to test for the effect on bacteria, (6) pasteurization to test for the effect of active forms of organisms, (7) Tyndallization to test for the effect of resting forms of organisms, or (8) water as a control. The effect was studied of inoculation with soil subjected to these treatments on number and types of ectomycorrhizas, on length of active mycelium, and on number of active bacteria in the rhizosphere. Inoculation with untreated forest or plantation soils increased the number of ectomycorrhizas but did not change the mycorrhizal types present. Most agents had different effects in different soils. Inoculation with pasteurized and Tyndallized clearcut and plantation soils increased the number of Rhizopogon- and Thelephora-type ectomycorrhizas and

decreased the number of active bacteria, as did untreated forest soil. It is hypothesized that the role of the soil transfer is to provide a rhizosphere environment free from a deleterious organism present in the clearcut. In this environment, beneficial organisms present in the clearcut or brought in with the seedling from the nursery can proliferate.

OSU Link
Non-OSU Link

36. Colinas, C., D. Perry, R. Molina and M. Amaranthus. 1994b. Survival and growth of Pseudotsuga menziesii seedlings inoculated with biocide-treated soils at planting in a degraded clearcut. Canadian-Journal-of-Forest-Research 24(8): 1741-1749.

Keywords: planting operations
fertilization
growth
tree/stand health
tree morphology

Abstract: To determine the factors of transfer soils responsible for increased seedling survival and growth, planting holes, at a site in SW Oregon, were inoculated with forest, plantation, and clear-cut soils subjected to one of 8 treatments: (i) treated with fertilizer to test for effects of nutrients; treated with biocides to test for effects of (ii) grazers (microarthropods or nematodes), (iii) protozoa, (iv) fungi, or (v) bacteria; (vi) pasteurized; (vii) Tyndallized; or (viii) untreated. Douglas fir (Pseudotsuga menziesii) seedlings were planted in June 1990 and seedling growth and survival was assessed in December 1990. Survival was increased by inoculation with untreated plantation soils, but not if they were fertilized or treated with dimethoate + carbofuran (grazercide), fumagillin (protozoacide), or oxytetracycline + penicillin (bactericide). Addition of untreated forest soil did not increase survival. For all soils, survival was increased by captan (fungicide), pasteurization and Tyndallization. Untreated plantation and forest soil transfers increased dry weights whereas neither did when treated with dimethoate + carbofuran. Dry weights of seedlings given clear-cut soil were increased by fertilization, pasteurization and Tyndallization of the soil; the latter two treatments also increased the number of short roots. It is hypothesized that stimulation of seedling growth by soil transfers was related to an increased rate of nutrient mineralization due to microbivorous soil animals contained within the transfer soils. Soil transfers may have enhanced seedling survival by at least two mechanisms: (i) by providing a safe site for beneficial rhizosphere organisms to proliferate, free from competing organisms that have proliferated in the clear-cut soil; and (ii) through volatile organic compounds, especially ethylene, that stimulated seedling root growth.

OSU Link
Non-OSU Link

37. Crouch, G.L. and M.A. Radwan. 1981. Effects of nitrogen and phosphorus fertilizers on deer browsing and growth of young Douglas-fir. Pacific-Northwest-Forest-and-Range-Experiment-Station,-USDA-Forest-Service. Research-Note PNW-RN-368. 15 p.

Keywords: fertilization
tree/stand health

growth
tree physiology

Abstract: N and P fertilizers were applied in March 1968 singly or in combination at a rate equivalent to 200 lb/acre of N or P to young trees (2-5 ft tall) in Oregon and Washington. Trees were examined and measured for up to 4 yr. In the first year after treatment trees given the N-only fertilizer in Washington were more heavily browsed by black tailed deer (Odocoileus hemionus columbianus), but this effect disappeared in the second year. Height growth was increased by N-only treatment in taller trees in Oregon after 1 and 2 yr, but the effect had disappeared after 4 yr. Total N content was significantly increased by the N and N + P treatments in the first year, but this effect also disappeared after 2 yr. The amounts of moisture, ash, Ca and P, and diam. growth were not affected by any treatments.

OSU Link
Non-OSU Link

38. Curtis, R.O., G.W. Clendenen and D.J. DeMars. 1981. A new stand simulator for coast Douglas-fir: DFSIM user's guide. Pacific-Northwest-Forest-and-Range-Experiment-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-128. ii + 79 p.

Keywords: planting operations
thinning
precommercial thinning
commercial thinning
fertilization
yield
computer modeling

Abstract: A description of a computer program, written in FORTRAN IV, for simulating managed stands. The program has been developed from remeasured plot data contributed by many organizations in the Pacific Northwest USA. It can produce yield tables which include estimates of effects of initial spacing, precommercial and commercial thinning and addition of N fertilizer. Topics discussed include program limitation and potential for further development. Appendices include operating instructions and notes on testing. The program is available from the authors on request.

OSU Link
Non-OSU Link

39. Dangerfield, J. and H. Brix. 1981. Comparative effects of ammonium nitrate and urea fertilizers on tree growth and soil processes. *In* Proceedings: Forest Fertilization
Conference, University of Washington, Seattle, Washington, USA. *Eds.* S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 133-139.

Keywords: fertilization
thinning
growth
tree physiology

Abstract: Growth response of Douglas-fir to ammonium nitrate and urea, applied at rates of 200 and 400 pounds per acre (224 and 448 kilograms of nitrogen per hectare), was studied over a 7-year period at Shawnigan Lake, B.C. Diameter growth was 21 and 9 percent better, respectively, for the two rates with ammonium nitrate than with urea in unthinned plots and 7 percent better for plots that had been thinned and received 400 pounds per acre (448 kilograms nitrogen per hectare). Foliar nitrogen concentrations also increased most with ammonium nitrate fertilzization during the first 2 years, indicating that nitrogen from this source was initially more readily available to the trees. This is explained in part by the greater mobility of nitrate supplied by ammonium nitrate and by nitrogen immobilization in buildup of bacterial populations with urea.

OSU Link
Non-OSU Link

40. DeBell, D.S., C.A. Harrington and J. Shumway. 2002. Thinning shock and response to fertilizer less than expected in young Douglas-fir stand at Wind River Experimental Forest. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-547. ii + 20 p.

Keywords: fertilization
thinning
precommercial thinning
growth

Abstract: Three thinning treatments (thinned to 3.7 by 3.7 m, thinned to 4.3 by 4.3 m, and an unthinned control treatment with nominal spacing averaging 2.6 by 2.6 m) were installed in a 10-year-old Douglas-fir (Pseudotsuga menziesii) plantation growing on a low-quality site at the Wind River Experimental Forest in southwest Washington, USA. Two years after thinning, two fertilizer treatments were superimposed on the design (0 and 224 kg per ha of nitrogen applied as ammonium nitrate). Diameter growth increased with increasing spacing throughout the 6-year study period, and it was also increased by fertilizer in both the thinned and unthinned (control) treatments. Thinning shock, a reduction in height growth after thinning, was expected at this study site because severe thinning shock had been documented in earlier nearby trials. Height growth was initially reduced slightly by thinning, but by the third 2-year period after thinning, height growth in thinned, unfertilized treatments was equal to or greater than height growth in the unthinned, unfertilized treatment. Fertilizer application increased height growth on average by 13 per cent in the first 2 years after fertilizer application. In the third and fourth years after fertilizer application, however, fertilizer increased average height growth by 9 per cent, but the increase was substantial (16 per cent) only in the unthinned control treatment. The mild, ephemeral nature of thinning shock in our study was in contrast to the severe, long-lasting shock in earlier studies at Wind River. The milder shock in our study could be related to one or more of the following: (1) thinning was done at an early age, (2) impacts of fire (natural or prescribed) preceding planting were minor, and (3) seed source of the planted stock was appropriate for the location. Based on comparisons with other studies at Wind River and elsewhere, we suspect that use of nonlocal, maladapted seed sources in the earlier studies may have predisposed those trees to thinning shock. Furthermore, we suspect that the much higher responses to fertilizer application reported in the earlier studies may be associated with intense natural fires prior to planting, and the reduced nutritional status of those sites may have been further exacerbated by the use of maladapted seed sources.

OSU Link
Non-OSU Link

41. DeBell, D.S., R.R. Silen, M.A. Radwan and N.L. Mandel. 1986. Effect of family and nitrogen fertilizer on growth and foliar nutrients of Douglas-fir saplings. Forest-Science 32(3): 643-652.

Keywords: fertilization
growth
tree physiology

Abstract: Urea (224 kg N/ha) was applied to 12-yr-old Douglas fir of 12 open-pollinated families growing near Corvallis, Oregon. Ht. and d.b.h. were measured before fertilization in Feb. 1979 and 4 growing seasons later, and tree vol. were estimated. Vol. increment varied among families, but was increased by an av. 7% by fertilizer. Concentrations of foliar nutrients, analysed in winter 1979 and 1980, differed significantly between families and in response to fertilization. The familyxfertilizer interaction was not significant for any growth or foliar nutrient measured.

OSU Link
Non-OSU Link

42. Dosskey, M.G., L. Boersma and R.G. Linderman. 1993. Effect of phosphorus fertilization on water stress in Douglas fir seedlings during soil drying. Plant-and-Soil 150(1): 33-39.

Keywords: fertilization
tree/stand protection
growth
tree physiology
photosynthesis

Abstract: A growth chamber experiment was conducted to determine if P fertilizing to enhance the P nutrition of otherwise N and P deficient Douglas fir (Pseudotsuga menziesii) seedlings reduces water stress in the seedlings during drought periods. Seedlings were grown in pasteurized mineral soil under well watered conditions and fertilized periodically with a small amount of nutrient solution containing P at three levels: 0, 20, or 50 mg/litre. By age 6 months, leaf nutrient analysis indicated that N and P were deficient in control (0 mg P/litre) seedlings. The highest level of P fertilizer, which doubled leaf P concentration, did not affect plant biomass, suggesting that N deficiency was limiting growth. When these seedlings were subjected to drought, there was no effect of P fertilizing on leaf water potential or osmotic potential. Furthermore, P fertilized seedlings had lower stomatal conductance and net photosynthesis rate. These results indicate that enhanced P nutrition, in the presence of N deficiency, does not reduce water stress in Douglas fir seedlings during drought periods.

OSU Link
Non-OSU Link

43. Driessche, R.v.-d. 1988b. Response of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) to some different fertilizers applied at planting. New-Forests 2(2): 89-110.

Keywords: nursery operations
nursery fertilization
fertilization
growth
tree/stand health
tree physiology

Abstract: Four fertilizer experiments to assess type of fertilizer, dosage and timing, were conducted on eastern Vancouver Island, BC, Canada. Two-yr-old, bare root planting stock was used except in experiment 3, where container stock was compared with bare root stock. Little growth response was obtained after one year, but height growth responses of 12 to 31% were measured after 3 to 6 yr with fertilizers supplying 8.4 to 16.8 g N per tree. Growth responses were little affected by type of fertilizer and were primarily due to N, with release rate having no marked effect. The exception to this was triple superphosphate which did not increase growth but did increase survival. Survival was reduced by ammonium sulphate and to a lesser extent by Agriform (NPK). Container seedlings responded more to fertilization at planting than bare root seedlings. Seedling N, P and K concn. and contents declined following planting for 6 months and only started to recover after July. Application of fertilizer caused a small increase in seedling nutrient concn. regardless of date, but this had no detectable effect on dry weight measured 6 wk later.

OSU Link
Non-OSU Link

44. Duke, K.M., G.M. Townsend and W.A. White. 1989. An economic analysis of fertilization and thinning effects on Douglas-fir stands at Shawnigan Lake. Canadian-Forest-Service, Pacific and Yukon Region Information-Report BC-X-312. v + 19 p.

Keywords: fertilization
thinning
economics
computer modeling

Abstract: A single-tree density-dependent growth model was used to project, from age 24 to age 120 yr, 9 combinations of thinning and fertilizer application (nitrogen as urea or ammonium nitrate) in Douglas fir (Pseudotsuga menziesii) near Shawnigan Lake, British Columbia. Costs and benefits were estimated as a function of stand diameter, and forestry investment criteria were used to evaluate each treatment on both an incremental and a regime basis. The effect of rising real prices, and the treatment of silvicultural costs as an initial investment or as a harvest cost were also studied.

OSU Link
Non-OSU Link

45. Edmonds, R.L. and T. Hsiang. 1987. Forest floor and soil influence on response of Douglas-fir to urea. Soil-Science-Society-of-America-Journal 51(5): 1332-1337.

Keywords: fertilization
thinning

growth
soil properties

Abstract: Data from the Regional Forest Nutrition Research Project (RFNRP) in Washington and Oregon were analyzed to improve stand-specific prediction of Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] response to urea fertilization. The response variable (relative difference in volume growth between fertilized and control plots 4 yr after fertilization with 448 kg N/ha) was regressed against 28 stand and site variables (e.g., age, elevation, forest floor C/N ratio, soil cation exchange capacity, etc.) using stepwise multiple regression analysis. Data from 120 installations were stratified by thinning level (thinned or unthinned), geographic location (provinces), and site quality (site index and class). Forest floor C/N ratio was the dominant variable related to response. In thinned installations of high site quality (site classes 1 and 2), 60% of variation in response was explained by the forest floor C/N, and 75% of the variation in response was explained with inclusion of surface soil exchangeable K. In thinned, low site quality stands, response was not as well related to forest floor C/N. Analysis of the data by province indicated that S may be limiting in southwest Oregon and P in coastal Washington.

OSU Link
Non-OSU Link

46. Entry, J.A., K. Cromack, Jr., R.G. Kelsey and N.E. Martin. 1991. Response of Douglas-fir to infection by Armillaria ostoyae after thinning or thinning plus fertilization. Phytopathology 81(6): 682-689.

Keywords: thinning
fertilization
tree/stand protection
growth
tree morphology
carbon allocation
tree/stand health
tree physiology

Abstract: Second-growth stands of Douglas-fir (Pseudotsuga menziesii) were thinned to a 5- x 5-m spacing (TT); additional plots were thinned and fertilized once with 360 kg of N (as urea)/ha (TF). An unthinned, unfertilized stand (UT) served as a control. Ten years after treatment, trees were inoculated with 2 isolates of A. ostoyae. Trees receiving the TF and TT treatments produced greater diameter growth, leaf area, and wood production/msuperscript 2 leaf area per year than did those under the UT treatment. Rates of infection by A. ostoyae were highest in trees that received the TF and lowest in trees that received the TT treatment. Concn of sugar, starch and cellulose in root bark tissue were highest in trees receiving the TF treatment and lowest in trees receiving TT treatment. Concn of lignin, phenolics and protein-precipitable tannins were highest in root bark from TT trees and lowest in root bark from TF trees. Biochemical parameters of root bark tissue were regressed with incidence of infection; coefficients of determination (rsuperscript 2) ranged from 0.07 (starch) to 0.57 (phenolic compounds). Ratios of the energetic costs of phenolic and of lignin degradation to the energy available from sugars (Epd:Eas and Eld:Eas) were correlated with incidence of infection (rsuperscript 2 = 0.77 and 0.70, respectively). It is concluded that thinning combined with fertilization may predispose P. menziesii trees to infection by A. ostoyae by lowering concn of defensive compounds in root bark and increasing the energy available to the fungus to degrade them.

OSU Link
Non-OSU Link

47. Feller, M.C., J.P. Kimmins and K.A. Scoullar. 1983. FORCYTE-10: calibration data and simulation of potential long-term effects of intensive forest management on site productivity, economic performance, and energy benefit/cost ratio. *In* I.U.F.R.B. Symposium on.Forest Site and Continuous Productivity; Seattle, Washington; August 22-28, 1982. *Eds.* R. Ballard and S.P. Gessel. Pacific-Northwest-Forest-and-Range-Experiment-Station, USDA-Forest-Service General-Technical-Report PNW-GTR-163 Part B. 179-200 pp.

Keywords: thinning
fertilization
soil properties
economics
computer modeling

Abstract: FORCYTE (FORest nutrient Cycling and Yield Trend Evaluator) is a computer simulation model of forest plant biomass production, litterfall, and decomposition, complete with nutrient cycling, nutrient limitation on growth, and a variety of management interventions. The model is a computerized approach to the estimation of the effects of varying thinning and fertilizer regimes, utilization level, and rotation length on site nutrient budgets, stand productivity, and the economic performance and energy efficiency of management. The model has evolved over 5 years to its present version FORCYTE-10, which is briefly described. Accompanying the development of FORCYTE, there has been a series of field research projects. Detailed biomass and biogeochemical descriptions of age sequences of Douglas-fir stands on both good and poor sites have been prepared for purposes of model calibration and testing. The present report summarizes some of the results of the FORCYTE-10 field studies on Vancouver Island, British Columbia, and presents some examples of the use of the model when calibrated with these data.

OSU Link
Non-OSU Link

48. Fight, R.D., J.M. Cahill, T.D. Fahey and T.A. Snellgrove. 1987a. Financial analysis of pruning coast Douglas-fir. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-390. ii + 17 p.

Keywords: pruning
fertilization
economics
wood quality
yield
computer modeling

Abstract: Unpruned stands of Douglas fir (Pseudotsuga menziesii) will yield little clear material under current management regimes in western Oregon and western Washington. Data from a recent study of grade recovery from pruned logs were analysed and a spreadsheet program was developed and used to simulate the increase in grade recovery and financial returns from pruning. Results are presented for a

range of site indices, ages at time of pruning and time of harvest, product prices and interest rates, and for stands with and without nitrogen fertilizer treatment. Results showed that a 5-yr difference in the time of pruning can make a substantial difference in the financial return. An earlier age at pruning always gave a higher return. At 4 and 8% interest rates, the return was generally greatest when the harvest was 40-50 yr or 30-40 yr, respectively, after pruning. Fertilizer treatment substantially increased the return from pruning, especially on poor sites.

OSU Link
Non-OSU Link

49. Fight, R.D., J.M. Cahill, T.D. Fahey and T.A. Snellgrove. 1988. A new look at pruning coast Douglas-fir. Western-Journal-of-Applied-Forestry 3(2): 46-48.

Keywords: pruning
thinning
fertilization
economics

Abstract: A short account of an evaluation of the financial returns of pruning coast Douglas fir (Pseudotsuga menziesii), using new product-recovery information and computer software, and assuming that: the analysis is for lumber, interest rates are 4 and 8%, stands are fertilized 2 or 3 times and thinned periodically, and that trees were pruned at age 20 yr. Results showed that higher returns from pruning could be achieved by concentrating pruning in younger stands that have a higher site index and that will be fertilized.

OSU Link
Non-OSU Link

50. Fox, T.R. 2004. Nitrogen mineralization following fertilization of Douglas-fir forests with urea in Western Washington. Soil-Science-Society-of-America-Journal 68(5): 1720-1728.

Keywords: fertilization
soil properties

Abstract: Nitrogen mineralization following repeated applications of urea fertilizer was determined in the A horizon soil from two stands of Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] in the Cascade Mountains of Washington. Repeated applications of urea at rates ranging from 0 to 600 kg N ha-1 were made at annual and 5-yr intervals over a 6-yr period. Nitrogen fertilization increased N mineralization potential in these soils. However, soil N mineralization followed a quadratic relationship with the total amount of N applied in fertilizer over the 6-yr treatment period, increasing up to total application rates of 450 kg N ha-1 and then declining at higher rates. The decrease in N mineralization rates at the high N fertilization rates may be due to changes in the quality of soil organic matter, which reduced the effectiveness of extracellular enzymes and decreases the rate of decomposition and mineralization. Soil pH dropped following urea fertilization, with greater declines observed in the highest rates of urea fertilizer. Decreases in extractable Ca and Mg levels in the soil accompanied the decline in soil pH. These results suggest that high rates of nitrification occurred and that nitrate leaching was stripping Ca and Mg from the cation-exchange complex in these soils. It appears that repeated applications of urea fertilizer

at low to intermediate rates may increase long-term N availability and thus improve soil quality. However, annual applications of high rates of urea may decrease soil quality because under these circumstances N mineralization did not increase and there was a loss of cations from the soil.

OSU Link
Non-OSU Link

51. Gardner, E.R. 1990. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 15-year growth response. Canadian-Forest-Service, Pacific and Yukon Region Information-Report BC-X-319. ix + 42 p.

Keywords: fertilization
thinning
growth
yield
tree morphology
tree/stand health

Abstract: Responses after 15 yr to 3 rates of nitrogen (urea), applied at 0, 224 or 448 kg N/ha to a 24-yr-old Douglas fir (Pseudotsuga menziesii) stand in the very dry maritime region of British Columbia, were analysed on the basis of per hectare, individual tree, crop tree and tree size class. Thinned and unthinned plots were measured.

OSU Link
Non-OSU Link

52. Gartner, B.L., J.J. Morrell, C.M. Freitag and R. Spicer. 1999. Heartwood decay resistance by vertical and radial position in Douglas-fir trees from a young stand. Canadian-Journal-of-Forest-Research 29(12): 1993-1996.

Keywords: fertilization
thinning
wood quality

Abstract: Heartwood durability of Douglas-fir (Pseudotsuga menziesii var. menziesii) was studied as a function of vertical and radial position in boles of trees with a wide range of leaf area/sapwood area ratios. Six 34-year-old trees were harvested from each of three plots: very dense, thinned, and thinned and fertilized with N, P, K, Ca, S and Fe (51, 11, 10, 7, 4 and 0.3 kg/ha, respectively), established 14 years before at a site in the central Cascades of Oregon. Heartwood samples from three radial positions and five heights were incubated with the decay fungus Postia placenta [Oligoporus placenta]. There were no significant differences in wood mass loss (decay resistance) by vertical or radial position. One could expect that trees with high leaf area/sapwood area could have the carbon to produce heartwood that is more resistant to decay than trees with lower leaf area/sapwood area. However, no relationship was found between leaf area above node 20, sapwood area there, or their ratio, and the decay resistance of outer heartwood at that node. These results suggest that, for young Douglas-fir trees, heartwood durability does not vary with position in the bole or with environments that alter the balance of

sapwood and leaf area in a tree. It is suggested that young stands may thus be robust with respect to the effect of silvicultural regimes on heartwood durability.

OSU Link
Non-OSU Link

53. Gertner, G.Z. 1984. Localizing a diameter increment model with a sequential Bayesian procedure. Forest-Science 30(4): 851-864.

Keywords: fertilization
growth

Abstract: A procedure is described for modifying a non-linear model taken from a regional forest growth projection system for use in a smaller subregion. Diameter growth monitored in the subregion of interest is used to adjust the parameters. The amount of adjustment required depends on the precision of the growth estimates from the regional model and of the estimates based on the local sample. More weight is given to the local estimates when their precision is relatively high in comparison with the regional estimates. An example is given of modifying a model developed for the Western Oregon Region for a Douglas fir stand in NW Oregon. In another example the procedure is used to adjust for the effects on diam. increment of fertilizing with urea.

OSU Link
Non-OSU Link

54. Gessel, S.P. and W.A. Atkinson. 1984. Use of fertilizers in sustained productivity of Douglas-fir forests. *In* Forest soils and treatment impacts: Proceedings, Sixth North American Forest Soils Conference, Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN, June 1983. pp. 67-87.

Keywords: fertilization
growth
economics

Abstract: A review is given of studies leading to the establishment of nitrogen deficiency as a factor reducing growth and the development of N fertilization programmes. Data from several long-term fertilizer trials in Washington and Oregon support the conclusion that N deficiency is frequently a controlling factor in the growth of Douglas fir and that additions of N can result in long-term growth increases. The economics of fertilization and the continued availability of nitrogen fertilizers are discussed.

OSU Link

55. Gessel, S.P., R.E. Miller and D.W. Cole. 1990. Relative importance of water and nutrients on the growth of coast Douglas fir in the Pacific Northwest. Forest-Ecology-and-Management 30(1-4): 327-340.

Keywords: fertilization
growth

soil properties

Abstract: The Douglas-fir region in northwestern North America is characterized by abundant moisture supply during winter, extended dry periods during the growing season and significant differences in water availability. Many soils have low fertility and indigenous tree species respond to nitrogen fertilization, especially Douglas fir (Pseudotsuga menziesii). Although irrigation of commercial forests in this region is currently impractical, questions arising about the relative importance of water and nutrients were examined using long-term growth data from three studies. At Pack Forest (Washington), fertilization without irrigation doubled growth rates, and no positive growth responses were measured from irrigation. Short-term (5 yr) irrigation with sewage effluent containing many nutrients resulted in a six-fold increase in biomass production for poplar and three-fold for Douglas fir as compared to irrigation with equal volumes of river water. Volume growth in 12- to 65-yr-old stands in southwestern Oregon was increased by fertilization at about 70% of the locations; annual gain averaged 2.73 msuperscript 3/ha for 5-12 yr. Response was not related to annual precipitation, which ranged from 81 to 279 cm, nor other moisture-related variables. Absolute and relative volume response showed highest correlation with soil carbon : nitrogen ratio. Compared with nutrition, moisture does not seem to be a major limiting factor for growth in the Douglas fir region of the Pacific Northwest.

OSU Link
Non-OSU Link

56. Gessel, S.P., E.C. Steinbrenner and R.E. Miller. 1981. Response of Northwest forests to elements other than nitrogen. In Proceedings: Forest Fertilization
Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 140-149.

Keywords: fertilization
growth
economics

Abstract: This paper reviews the development of forest tree nutrition research in the Northwest. Field observations, foliar analysis, and greenhouse cultures using both solution and forest soil as media established deficiency symptoms and levels for major and minor elements. Field experimentation with the entire range of essential elements has failed to demonstrate widespread deficiencies of elements other than nitrogen. Certain test areas have shown somewhat better response to combinations of elements; but because of the limitations of experimental design and field variation, the response does not generally have a high statistical significance. In some cases of apparent response, application of fertilizer materials other than nitrogen does not appear to be economic. There is sufficient evidence of response to other elements to suggest that much work needs to be done. Increased utilization of forest materials, shorter rotation, and greater yields with nitrogen fertilization all point to the fact that many of the Northwest forest areas could have future elemental deficiencies, other than nitrogen.

OSU Link
Non-OSU Link

57. Graff, J.E., Jr., R.K. Hermann and J.B. Zaerr. 1999b. Ionic balance and organic acids in western redcedar, western hemlock, and Douglas-fir seedlings grown in low- and high-N soils. Canadian-Journal-of-Forest-Research 29(6): 669-678.

Keywords: fertilization
tree physiology

Abstract: Seedlings of western redcedar (Thuja plicata), western hemlock (Tsuga heterophylla) and Douglas fir (Pseudotsuga menziesii) were transplanted into soils collected in early May 1987 from 2 sites with low (near Carson, Washington) and high (near the Oregon coast) levels of available NO3- (and total N). Current-year foliage was sampled after 10 weeks to determine the effect of N availability on foliar cation-anion balance (C-A) and the concentrations of low molecular weight organic acids of the 3 species. Carboxylate concentrations were estimated by using the difference between sums of cations and anions (C-A): 750 mequiv/kg for Thuja plicata, 351 mequiv/kg for Tsuga heterophylla and 266 mequiv/kg for P. menziesii. Quinic acid was a primary constituent, accounting for 40% of the total for Thuja plicata and 75% for Tsuga heterophylla and P. menziesii. Oxalic acid was present in greatest concentration in the foliage of Thuja plicata (65 mequiv/kg) but was a minor constituent in both other species. The quantified acids accounted for only 15% of the C-A of Thuja plicata but >80% of the C-A of the other species. It is suggested that a considerable portion of the C-A balance not accounted for in Thuja plicata may be associated with the accumulation of CaCO3 and that litterfall deposition of CaCO3 may lead to the consumption of H+ ions and enrichment of exchangeable soil Ca in the rooting zone of long-lived Thuja plicata trees. No statistically significant differences between the soils were detected with regard to C-A or the concentration of organic acids.

OSU Link
Non-OSU Link

58. Green, R.N. and R.E. Carter. 1993. Boron and magnesium fertilization of a coastal Douglas-fir plantation. Western-Journal-of-Applied-Forestry 8(2): 48-53.

Keywords: fertilization
growth
tree/stand health
tree physiology

Abstract: A study was made of the role of boron and magnesium nutrition in the occurrence of severe growth distortion symptoms in Douglas-fir (Pseudotsuga menziesii) in the Skwawka River valley of south coastal British Columbia. Four fertilizer treatments, including boron (2.25 kg/ha B), magnesium (42 kg/ha Mg), boron plus magnesium, and a control, were applied in conjunction with planting on a site believed to be deficient in these nutrients. After 5 growing seasons, only treatments containing boron (B and B + Mg) showed improved height growth compared to controls. The incidence of leader dieback, swollen leading shoots, and foliage distortion was significantly related to treatment, with virtually no occurrence in plots treated with boron. Seedling uptake of applied boron was high, with foliar concentrations of 45 p.p.m. found after the second growing season. Foliar B levels declined to 13-15 p.p.m. after 5 growing seasons. No significant increase in foliar magnesium levels was detected for either of the magnesium treatments. The reduction in the incidence of leader dieback, and shoot and foliar symptoms, in seedlings treated with B indicate that these symptoms were the result of boron deficiencies. This is the first study to verify boron deficiency in coastal Douglas fir through fertilizer trials.

OSU Link
Non-OSU Link

59. Grier, C.C., K.H. Lee and R.M. Archibald. 1984. Effect of urea fertilization on allometric relations in young Douglas-fir trees. Canadian-Journal-of-Forest-Research 14(6): 900-904.

Keywords: fertilization
growth
carbon allocation
tree morphology

Abstract: Twenty three yr old trees growing on a class III site in Washington State were fertilized with 225 kg/ha N in March 1980. Trees were measured before fertilizing and after 1980-83 growing seasons and destructively sampled after 2 growing seasons (in Nov.-Dec. 1981 and Jan. 1982). Logarithmic regression equations using stem diam. to predict tree biomass components were not significantly (p = 0.05) different between fertilized and control trees for total foliage, total branch, dead branch, stembark, or stemwood. New foliage and new twig components, however, were higher in fertilized trees than in control trees. Analysis of data from this and earlier studies suggests that fertilizing will increase leaf biomass per tree relative to control trees on sites having low nitrogen availability; however, this response will decrease with increasing nitrogen availability. Regression equations based on regional analysis of unfertilized trees yield estimates of foliage biomass for average trees on average sites. If N fertilizing brings the site above average in terms of nitrogen availability then these regression equations will underestimate foliage biomass. However, on sites that are initially very nitrogen deficient, N fertilizing will bring the site closer to average in terms of nitrogen availability, resulting in more accurate predictions of foliage biomass for fertilized stands than for control stands.

OSU Link
Non-OSU Link

60. Hall, T.H., R.V. Quenet, C.R. Layton and R.J. Robertson. 1980. Fertilization and thinning effects on a Douglas-fir ecosystem at Shawnigan Lake: 6 year growth response. Pacific-Forest-Research-Centre, Canadian Forestry Service Information-Report BC-X-202. 31 p.

Keywords: fertilization
thinning
growth

Abstract: Further results are given for this stand in British Columbia at 30 yr old [see FA 43, 1945]. Gains in gross vol. increment (over control at 24 yr old) for the 200 initially largest trees/ha were 20% for heavy thinning alone, 51% for heavy fertilizer (urea) application alone and 139% for heavy thinning plus heavy fertilizer application. Adjustments by covariance analysis for differences in intitial stocking and tree size distributions gave values of 47, 76 and 139% respectively.

OSU Link
Non-OSU Link

61. Harrison, R., D.S. Xue, C. Henry and D.W. Cole. 1994a. Long-term effects of heavy applications of biosolids on organic matter and nutrient content of a coarse-textured forest soil. Forest-Ecology-and-Management 66(1/3): 165-177.

Keywords: fertilization
soil properties

Abstract: Long-term changes in soil properties due to a single heavy application of municipal biosolids (municipal sewage sludge) on a coarse-textured glacial outwash soil were evaluated. Study sites, located at the Pack Experimental Forest, 100 km S. of Seattle, Washington, were clearcut, cleared, fertilized with 500 t/ha of municipal biosolids and planted with either Lombardy poplar (Populus nigra var. italica), Douglas fir (Pseudotsuga menziesii) or ponderosa pine (Pinus ponderosa) in 1975. Soil samples were taken in 1990 from treated stands and from adjacent (unamended) control sites by horizon to a depth of 185 cm. Biosolids-amended samples had greater amounts (mg/g) of C (139 vs. 67), N (12 vs 3.4), P (14 vs. 2.2) and S (2.5 vs. 0.4) contents in 0-7 cm mineral soil and other surface soil horizons, compared with control soil horizons, but showed no significant differences below 25 cm. Soil pH ranged from 0.4 to 1.0 units lower in biosolids-amended vs. unamended soil throughout the sampled soil horizon. Soil cation exchange capacity was higher in the surface soil horizons of treated plots (30 vs. 18 mmolc kg-1 in 0-7 cm soil), but there were no significant differences below 50 cm. Biosolids-amended samples had greater amounts (mg/g) of total Ca (13 vs. 6.1 in 0-7 cm soil) and K (1.9 vs. 1.5 in 0-7 cm soil) throughout the sampled soil profile. Total Mg was relatively constant (2.0-3.0) throughout the sampled soil profile. Study results indicate that one of the primary objectives of the original biosolids application (increasing total nutrients in the rooting zone of the forest soil) extended at least 15 years from the application date.

OSU Link
Non-OSU Link

62. Harrison, R.B., S.P. Gessel, D. Zabowski, C.L. Henry, D.S. Xue, D.W. Cole and J.E. Compton. 1996. Mechanisms of negative impacts of three forest treatments on nutrient availability. Soil-Science-Society-of-America-Journal 60(6): 1622-1628.

Keywords: fertilization
growth
soil properties
tree/stand health

Abstract: Many forest management treatments are directly aimed at maintaining or enhancing forest productivity. There may also be secondary effects that detract from this goal. Three case studies in Washington state, USA, are discussed in which several mechanisms may have led to adverse secondary impacts. In the first study, pulp and paper (PIT) sludges were mixed into soil and growth of Douglas-fir (Pseudotsuga menziesii), noble fir (Abies procera) and western white pine (Pinus monticola) was monitored. There was a significant negative correlation of height and diameter growth and C:N ratio for Douglas-fir and western white pine. In a second study, effects of 50 years of red alder (Alnus rubra) and Douglas-fir growth on soil chemistry and stand productivity were compared. When the 50-year-old stands were cut and red alder was established by planting into the soil of the former Douglas-fir and red alder forests, a reduction in available P in the soil of the previous red alder stand was observed. In a third study, high rates of low C:N ratio organic matter (300 t/ha) were added in municipal biosolids

(~8000 kg N/ha) to Douglas-fir and grand fir (Abies grandis) plantations. Excess organic N in the biosolids apparently mineralized, nitrified, and contributed to soil acidification and accelerated cation leaching. Severe Mg deficiency (0.25 g/kg in biosolids-treated vs. 0.93 g/kg in untreated areas) might be the cause of observed foliar chlorosis and poor growth rates.

OSU Link
Non-OSU Link

63. Harrison, R.B., C.L. Henry, D.W. Cole and D. Xue. 1995. Long-term changes in organic matter in soils receiving applications of municipal biosolids. *In* Carbon forms and functions in forest soils. *Eds.* W.W. McFee and J.M. Kelly. Soil Science Society of America Inc., Madison WI. pp. 139-153.

Keywords: fertilization
soil properties

Abstract: Soil concn of C, N, P, Ca, Mg, K, pH, and CEC were compared at two forest sites of contrasting mineralogy and management in Washington, U.S.A., after the application of municipal biosolids. The soil on the Pack forest site was an extremely coarse-textured outwash soil whilst that of the Mt. Pilchuck Tree Farm was a sandy outwash soil. The Pack forest was characterized by 80-yr-old second growth Douglas fir (Pseudotsuga menziesii) with an understory of salal (Gaultheria shallon). The Mt. Pilchuck Tree Farm site was characterized by 60-yr-old second growth Douglas fir with an understory of salal. Both sites were harvested and cleared prior to the initiation of the studies. The forest floors were different in the biosolids-amended soils compared with the unamended soils, with more highly humified material and fewer fine roots. Large increases in C, N, and P concn in the amended plots were restricted to the top 27 cm of soil. Ca and Mg increases were observed at the Pack Forest amended site but not at the Mt. Pilchuck Tree Farm site. At both sites the pH was lower in the amended plots. The differences between the sites are discussed with reference to soil type and management practices. Implications for long-term nutrient retention are considered.

Non-OSU Link

64. Harrison, R.B., C.L. Henry and D.S. Xue. 1994b. Magnesium deficiency in Douglas-fir and grand fir growing on a sandy outwash soil amended with sewage sludge. Water, Air, and Soil Pollution 75(1/2): 37-50.

Keywords: fertilization
tree/stand health
tree physiology
soil properties

Abstract: Soil and plant samples were collected from chlorotic plantations of grand fir (Abies grandis) and Douglas fir (Pseudotsuga menziesii) near Seattle, Washington state, USA, in winter 1989. The soils had been amended in 1981 with an average of 300 dry t/ha of municipal sewage sludge. The sludge amendment resulted in an N application rate of approximately 8000 kg/ha. Foliage analysis indicated that a severe Mg deficiency (0.25 g/kg in sludge-treated vs. 0.93 g/kg in untreated areas) might be the cause of chlorosis. No other nutrient showed concentrations in the deficient or toxic ranges. Trace metal levels in foliage were increased significantly for Ni, Cd and Cr at sludge-treated sites, but were not at

toxic levels. Soil samples taken to a depth of 1.4 m indicated the potential for soil acidification (up to 0.9 pH unit) in soil surface horizons. In addition, exchangeable Ca, Mg and K may have been depleted in surface horizons. Exchangeable Al and Fe were greater in the surface of sludge-treated sites. These observations, and the loss of much of the nitrogen added during the sludge amendment, indicated that nitrification and cation leaching were the most likely mechanism for acidification and depletion of exchangeable cations. Fertilizing the plantation with MgSO4 or dolomitic limestone was carried out in spring 1990. New foliage collected in June 1990 was non-chlorotic and significantly higher in Mg concentration than unfertilized foliage (1.1. vs. 0.7 g/kg, respectively). The results of this study indicate that it is important to assess the potential for initiating a nutrient deficiency due to secondary effects of sludge application in forest systems.

OSU Link
Non-OSU Link

65. Harrison, R.B., E.C. Turnblom, C.L. Henry, P. Leonard, R. King and R. Gonyea. 2002. Response of three young Douglas-fir plantations to forest fertilization with low rates of municipal biosolids. Journal-of-Sustainable-Forestry 14(2/3): 21-30.

Keywords: fertilization
growth
tree/stand health

Abstract: Growth responses were monitored in three Pseudotsuga menziesii stands (Units 2, 11 and 13) in Washington, USA, following single low applications (17-19 t/ha) of municipal biosolids amendment. At the last measurement, in 1995, there were a total of 162 vs. 137 live trees (per 0.121 ha of 3 plots) in unit 2, 94 vs. 137 in unit 11, and 100 vs. 110 in unit 13 in control vs. biosolids-treated plots, respectively. The response ranged from 0.4 to 2.2 cm for average diameter at breast height, and -0.03 to 0.64 m for average total height. The small negative response could be due to mortality of trees or small errors in height measurements. The response in per ha values ranged from 0.8-5.2 m2/ha for basal area, 9-39 m3/ha for volume, and 3965-16 107 kg/ha for dry weight.

OSU Link
Non-OSU Link

66. Heath, L.S. and H.N. Chappell. 1989. Growth response to fertilization in young Douglas-fir stands. Western-Journal-of-Applied-Forestry 4(4): 116-119.

Keywords: fertilization
thinning
growth

Abstract: Response surface methodology was used to estimate 6-yr vol. growth response to 1 application of 200 lb N/acre in unthinned and thinned Douglas fir (Pseudotsuga menziesii) stands of b.h. age <less or =>25 yr in W. Washington and W. Oregon. Regional mean fertilizer response was 16% in unthinned stands and 20% in thinned stands. Site index had an increasingly inverse effect on response as b.a. increased in both unthinned and thinned stands. Response varied little over site index in regions

of low b.a., decreased moderately as site index increased in the intermediate region, and decreased rapidly in the high b.a. region.

OSU Link
Non-OSU Link

67. Henry, C.L., D.W. Cole and R.B. Harrison. 1994. Use of municipal sludge to restore and improve site productivity in forestry: The Pack Forest Sludge Research Program. Forest-Ecology-and-Management 66(1/3): 137-149.

Keywords: fertilization
growth
soil properties
stand conditions

Abstract: Municipal wastewater residuals - sludge or biosolids - represent a major waste by-product from society that must be managed in responsible ways. Because of its high nutrient and organic matter content, sludge can be beneficially recycled into forest sites for site improvement purposes. This paper reviews the opportunities and problems that have been encountered during 20 yr of research into sludge application in forests, based on data from studies carried out in the Pack Demonstration Forest, Washington, on a variety of sites - including clear-felled, young or mature Douglas fir [Pseudotsuga menziesii] stands, and rights-of-way. Research to date on forest application of sludge has been very encouraging, clearly demonstrating the validity of this management technique. Forest sites typically display benefits in two ways: (1) an immediate growth response by both overstorey and understorey species; (2) a long-term improvement to the productivity of the site. However, for this practice to have broad utility and acceptance, it is critical that the concerns of the regulatory agencies and general public be addressed regarding public health and environmental issues through continued research. These concerns include the fate of trace metals, including movement, uptake and potential phytotoxicity, and passage into wildlife and human food chains, the fate of pathogens, and leaching of nitrates into groundwater systems. Many concerns are a result of misconceptions or misunderstandings of the potential problems involved and require working with these agencies and the general public through education and demonstration programmes.

OSU Link
Non-OSU Link

68. Henry, C.L., D.W. Cole, T.M. Hinckley and R.B. Harrison. 1993. The use of municipal and pulp and paper sludges to increase production in forestry. Journal-of-Sustainable-Forestry 1(3): 41-55.

Keywords: nursery operations
nursery fertilization
fertilization
thinning
growth
tree/stand health
soil properties

Abstract: Because of their high nutritional content and soil conditioning properties, municipal and pulp and paper (P&P) sludges (biosolids) can serve as soil amendments for nutritionally deprived or organically poor soils on forest sites. Studies conducted over the past 20 years at an experimental forest site in Western Washington, USA, have largely confirmed the potential of biosolids to increase the productivity of many forest lands. These studies clearly demonstrated that application of biosolids at environmentally acceptable rates will result in growth responses for both young seedlings as well as established stands. Municipal biosolids have been applied to a number of Douglas fir (Pseudotsuga menziesii) stands. Young stands treated with 47 t/ha showed an average of 72, 14 and 2% height responses for Site Class IV, III and II, respectively, over a 10 year period. Thinned versus unthinned 55-year-old Douglas fir treated with 142 dry t/ha averaged 43 and 48%, respectively, for the 12 year period greater than controls. Average growth responses of 65 and 40% occurred in the 65-year-old stand for the Site Class IV and II, respectively, from a 47 dry t/ha application. Growth response resulting from application of P&P biosolids to a number of tree species (Douglas fir, Pinus monticola and Abies procera in nursery beds, and plots of Populus deltoides x P. trichocarpa rooted cuttings) has also been excellent. When properly applied, biosolids can provide an excellent alternative to chemical fertilizers as a means of enhancing forest production. Growth response is typically greater and lasts longer when compared with chemical fertilizers.

OSU Link
Non-OSU Link

69. Hermann, R.K. and D.P. Lavender. 1999. Douglas-fir planted forests. New-Forests 17(1/3): 53-70.

Keywords: genetic tree improvement
nursery operations
planting operations
site preparation
release treatments
fertilization
thinning
pruning
tree/stand protection
growth
yield

Abstract: A combination of superior wood quality and high productivity has made Douglas fir (Pseudotsuga menziesii) one of the premier timber trees in the world. As such, it is grown as a plantation species in several countries in Europe and South America, and in New Zealand and Australia, as well as throughout its extensive natural range in western North America. Decades of experience with the silviculture of young stands have demonstrated that practices such as planting, the use of genetically improved seedlings, precommercial and commercial thinning, and fertilizing may dramatically increase the yield of industrial products over that of natural forests. Further, such silviculture is compatible with the production of desired amenities. Vigorous implementation of such practices wherever Douglas fir is cultivated will increase the world's timber resources, and be an effective strategy for reducing the pressure, occasioned by the world's rapidly increasing population, to harvest the fragile tropical and boreal forests.

OSU Link
Non-OSU Link

70. Hetherington, E.D. 1985. Streamflow nitrogen loss following forest fertilization in a southern Vancouver Island watershed. Canadian-Journal-of-Forest-Research 15(1): 34-41.

Keywords: fertilization
soil properties

Abstract: Water quality was monitored in the Lens Creek catchment to determine nitrogen loss following aerial application of 224 kg/ha N (as urea) to a second-growth Douglas-fir forest in Sept. 1974. Peak nitrogen concentrations measured in 2 small tributary streams were 14 mg/litre as urea (after 12 h), 1.9 mg/litre as ammonia (after 24 h), and 9.3 mg/litre as nitrate (after 7 wk). For the first 14 months, estimated nitrogen outputs in excess of background amounts were 5.9 and 14.5% respectively of the total nitrogen applied to the 2 subsidiary catchments which had 46 and 80% of their drainage areas fertilized. These losses were considerably higher than amounts of <1% previously reported for western North America. Increased amounts of urea N and ammonia N were short-lived, while nitrate N remained above background values for the duration of the study. Reasons for the high nitrogen loss include nitrification of the urea during 7 wk of mild, dry weather following fertilizing, the presence of alder and swampy areas adjacent to the streams, high soil permeability, steep slopes, and abundant, above average early winter rainfall. The catchments had been fertilized previously in 1967-68 and 1972 but any influence of this on nitrogen loss during the present study is unknown. Lens Creek water quality was not adversely affected by the fertilizing in terms of drinking water standards or toxicity to fish.

OSU Link
Non-OSU Link

71. Homann, P.S., B.A. Caldwell, H.N. Chappell, P. Sollins and C.W. Swanston. 2001. Douglas-fir soil C and N properties a decade after termination of urea fertilization. Canadian-Journal-of-Forest-Research 31(12): 2225-2236.

Keywords: fertilization
soil properties

Abstract: Chemical and microbial soil properties were assessed in paired unfertilized and urea fertilized (>89 g N/m-2) plots in 13 second-growth Douglas fir (Pseudotsuga menziesii) stands distributed throughout western Washington and Oregon, USA. A decade following the termination of fertilizer application, fertilized plots averaged 28% higher total N in the O layer than unfertilized plots, 24% higher total N in surface (0-5 cm) mineral soil, and up to four times the amount of extractable ammonium and nitrate. Decreased pH (0.2 pH units) caused by fertilizer application may have been due to nitrification or enhanced cation uptake. In some soil layers, fertilizer application decreased cellulase activity and soil respiration but increased wood decomposition. There was no effect of fertilizer application on concentrations of light and heavy fractions, labile carbohydrates, and phosphatase [phosphoric monoester hydrolases] and xylanase activities. No increase in soil organic C was detected, although variability precluded observing an increase of less than ~15%. Lack of a regionwide fertilizer application influence on soil organic C contrasts with several site-specific forest and agricultural studies that have shown C increases resulting from fertilizer application. Overall, the results indicate a substantial residual

influence on soil N a decade after urea fertilizer application but much more limited influence on soil C processes and pools.

OSU Link
Non-OSU Link

72. Hong, S. and J.J. Morrell. 1997. Treatability of Douglas-fir heartwood with ACZA or CCA: effect on site, silvicultural practice, and wood properties. Forest-Products-Journal 47(10): 51-55.

Keywords: planting operations
fertilization
thinning
wood quality

Abstract: The effects of site, silvicultural treatments, and wood properties on treatability of Douglas-fir (Pseudotsuga menziesii) heartwood, from Washington and Oregon, with chromated copper arsenate (CCA) or ammoniacal copper zinc arsenate (ACZA) were studied. Thinning appeared to be associated with slight improvements in treatability (penetration and retention of preservative), but combinations of thinning and fertilization had no significant effect on this property. Other factors such as site, height from which the sample was removed, and percentage of juvenile wood had inconsistent effects on treatability. Although the results indicate that silvicultural practices have minimal effects on treatability of Douglas-fir, further studies are required to clarify these effects.

OSU Link
Non-OSU Link

73. Hopmans, P. and H.N. Chappell. 1994. Growth response of young, thinned Douglas-fir stands to nitrogen fertilizer in relation to soil properties and tree nutrition. Canadian-Journal-of-Forest-Research 24(8): 1684-1688.

Keywords: fertilization
growth
soil properties
tree physiology

Abstract: Application of 224 kg N/ha to young, thinned stands of Douglas fir (Pseudotsuga menziesii) at 35 sites in W. Oregon and Washington significantly increased basal area and volume increment over 8 years following treatment. However, response varied considerably between sites, and relative volume increment exceeded 10% at only 19 of the 35 sites. Response to applied N was evaluated in relation to forest floor and soil variables as well as to levels of N in foliage. Relative responses in basal area and volume were significantly correlated with total N concentration and the C/N ratio of the soil. However, these relationships explained only part (18-22%) of the observed variation in response. In contrast, relative response was strongly correlated with the level of N in the foliage of non-fertilized trees at 11 sites, accounting for 94% of the variation between sites. It is suggested that foliar N could be used to predict growth responses to N fertilizers in young thinned Douglas fir stands.

OSU Link
Non-OSU Link

74. Jacobs, D.F., R. Rose, D.L. Haase and P.D. Morgan. 2003b. Influence of nursery soil amendments on water relations, root architectural development, and field performance of Douglas-fir transplants. New-Forests 26(3): 263-277.

Keywords: nursery operations
fertilization
tree physiology
tree morphology
growth
carbon allocation
soil properties
tree/stand health

Abstract: This experiment evaluated the influence of manure, peat, and vermiculite incorporated at low and high rates (0.0118 and 0.0236 m3/m2) and under two soil moisture regimes on Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedling (1+0 for 1+1) xylem water potential (Phi xylem), whole-plant growth, root architectural development, and subsequent field performance under fertilized and non-fertilized conditions. Trends in soil moisture retention were observed (high manure > high peat > control) but there were no differences in Phi xylem. Root length in the wetter soil moisture experiment was initially (three months) greatest for seedlings in high vermiculite and least in high manure but there were no differences among treatments at lifting (eight months). Mean height was greatest for seedlings grown in vermiculite and peat (wetter nursery experiment) after two field seasons. Field fertilization (35 g/seedling) with controlled-release fertilizer in the planting hole stimulated height growth initially, but decreased height and diameter growth during the second growing season. Dramatic improvements associated with the use of nursery soil amendments were not realized, but the failure to identify negative effects, a potential reduction in disease incidence, and improvement of nursery soil physical and chemical properties may justify their use.

OSU Link
Non-OSU Link

75. Jozsa, L.A. and H. Brix. 1989. The effects of fertilization and thinning on wood quality of a 24-year-old Douglas fir stand. Canadian-Journal-of-Forest-Research 19(9): 1137-1145.

Keywords: fertilization
thinning
wood quality
growth

Abstract: The effect of thinning and N fertilization on growth and wood density of coastal Douglas fir (Pseudotsuga menziesii) on a poor site on Vancouver Island (British Columbia) is described for plots established at approx. 24 yr old in 1971-72. Stem cores were taken using an increment borer in Mar.-Apr. 1984. Ring-width and ring-density data were obtained from pith to bark for all trees using computerized X-ray densitometry. Fertilization reduced ring density at b.h. and 25% stem ht. by an av. of

6% for a 3- to 4-yr period after treatment, but not thereafter. Reductions in ring density resulted from decreases in the density of earlywood and latewood, as well as from decreases in latewood percentages. Effects were only pronounced in the lower half of the stem. Thinning resulted in a slight increase in ring-density in the lower bole and a reduction in the top. The combined treatments had an intermediate effect on ring density. Ring density showed an increasing trend from pith to bark at all ht. except at 75% stem ht., and a decrease with increasing ht. in the bole. Fertilization and thinning both increased diam. growth, and the beneficial effects were still evident 13 yr after treatments.

OSU Link
Non-OSU Link

76. Kabzems, R.D. and K. Klinka. 1987. Initial quantitative characterization of soil nutrient regimes. I. Soil properties. Canadian-Journal-of-Forest-Research 17(12): 1557-1564.

Keywords: fertilization
soil properties

Abstract: Data on properties of the forest floor and mineral soil were collected from 6 Douglas fir ecosystems on southern Vancouver Island. Data were analysed to determine whether soil properties reflecting nutrient status differed significantly from soil nutrient regimes assessed using selected vegetation, environmental and physiographic features. The sum of mineralizable N, total N and exchangeable Ca and Mg in mineral soil and forest floor were the properties that best characterized the soil nutrient regimes recognized in this study (poor, medium, rich, very rich). Previous application of N fertilizer did not appear to change soil N status sufficiently to alter the classification. Both discriminant and cluster analyses consistently differentiated the soil nutrient regimes using exchangeable Mg and mineralizable N in forest floor plus mineral soil. The consistency of these groupings suggests that important differences between the nutrient regimes could be identified using soil properties alone.

OSU Link
Non-OSU Link

77. Kershaw, J.A., Jr. and D.A. Maguire. 1996. Crown structure in western hemlock, Douglas-fir, and grand fir in western Washington: horizontal distribution of foliage within branches. Canadian-Journal-of-Forest-Research 26(1): 128-142.

Keywords: fertilization
tree morphology

Abstract: Horizontal distribution of foliage within individual branches was explored for western hemlock (Tsuga heterophylla), Douglas fir (Pseudotsuga menziesii) and grand fir (Abies grandis), three major tree species in the Pacific Northwest. Weibull, beta , normal, and Johnson's SB distributions were assessed for their ability to conform to the empirical foliage distributions. Moment-based parameter recovery and parameter prediction methodologies were applied. On the basis of the rank of individual branch chi superscript 2-values, the beta distribution performed best under parameter recovery, while Johnson's SB distribution was best in terms of total sum of chi superscript 2-values. Overall, few differences between the four distributions were observed. A system of moment-based parameter prediction equations was developed from branch dimensional and positional measures. The prediction equations

showed that the ratio of relative distances from the stem to mean foliage density increased with increasing branch size. This relative increase was enhanced with increasing depth into crown for western hemlock, but not for Douglas fir or grand fir. Again, the beta distribution, based on predicted moments, followed most closely the empirical distributions on the basis of the ranks of chi superscript 2-values. The normal distribution was the best in terms of total sum of chi superscript 2-values. As expected, moment-based parameter recovery produced smoothed distributions that followed more closely the observed empirical distributions; however, parameter prediction provides a methodology for predicting distributions when empirical moments are not available. No significant ($p > 0.05$) differences in horizontal foliage distribution were found between sites or fertilizer (0 or 225 kg N/ha as urea) treatments.

OSU Link
Non-OSU Link

78. Kimball, B.A., E.C. Turnblom, D.L. Nolte, D.L. Griffin and R.M. Engeman. 1998b. Effects of thinning and nitrogen fertilization on sugars and terpenes in Douglas-fir vascular tissues: implications for black bear foraging. Forest-Science 44(4): 599-602.

Keywords: fertilization
thinning
tree/stand protection
tree physiology
tree/stand health

Abstract: Analyses of vascular tissue samples from Douglas fir (Pseudotsuga menziesii) trees collected in test plots in W. Washington and NW Oregon, USA, showed that both thinning and N fertilizer application caused the sugar concentration of vascular tissues in the lower bole to increase. However, these treatments had no effect on the concentrations of hydrocarbon monoterpenes, oxygenated monoterpenes or sesquiterpenes. These results may explain the observations that black bears (Ursus americanus) prefer to forage in thinned and fertilized stands, as the bears maximize sugar intake and minimize terpene intake while foraging.

OSU Link
Non-OSU Link

79. Lavender, D.P. and R.B. Walker. 1981. Nitrogen and related elements in nutrition of forest trees. In Proceedings: Forest Fertilization Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 15-22.

Keywords: fertilization
tree physiology
soil properties
mycorrhizal response

Abstract: This paper discusses the principal inorganic ions used by forest trees and their respective roles in tree physiology, their common range of concentration in coniferous foliage, and the general symptoms associated with their deficiency. The factors governing effective concentrations of each ion at

an active metabolic site are redistribution or internal nutrient cycling, nutrient uptake, and soil status (temperature, moisture, and concentration of each nutrient). Also described are endogenous patterns of nutrient storage and translocation, and the possible effects of fertilizers upon them and upon the mechanisms of ion uptake, especially the effect of pH change associated with urea applications upon the mycorrhizal complement of western hemlock (Tsuga heterophylla).

OSU Link
Non-OSU Link

80. Lee, Y.J. and H.J. Barclay. 1985. Ten-year growth response of a 25-year-old and a 55-year-old Douglas-fir stand to thinning and urea fertilization. Pacific-Forestry-Centre, Canadian-Forest-Service Information-Report BC-X-260. 14 p.

Keywords: fertilization
thinning
growth
tree/stand health

Abstract: In stands of medium site quality in British Columbia, 4 rates of nitrogen (0, 112, 224, and 336 k/ha of N), in the form of urea (46% N), were tested at two thinning intensities. Fertilizer was applied in spring or fall, but the season of application had little effect on growth. Thinning almost doubled diam. growth by 10 yr but affected only net vol. growth; gross vol. was only minimally affected by thinning. Fertilization in the 25-yr-old stand increased mean d.b.h. growth significantly in the second and third yr and increased vol. growth significantly in the first 3 yr, but the effect diminished thereafter. Different rates of fertilizer application on the 55-yr-old stand gave inconsistent results. Combined thinning and fertilizer treatment had the greatest growth response. In both stands the overall effect of 336 kg/ha N was to increase vol. growth by about 20%. Thinning significantly decreased mortality, but the effect of fertilizer was negligible. Combined treatment had the greatest effect on the advancement of trees by the number of d.b.h. classes. The effect of thinning and fertilizing on the cumulative growth will probably continue after 10 yr until crowding sets in.

OSU Link
Non-OSU Link

81. Luxmoore, R.J., M.L. Tharp and R.A. Efroymson. 1999. Comparison of simulated forest responses to biosolids applications. Journal-of-Environmental-Quality 28(6): 1996-2007.

Keywords: fertilization
growth

Abstract: Organic matter and N were added to humus pools of the LINKAGES simulator of forest growth and N cycling at a range of application rates to investigate long-term effects of biosolids (sewage sludge) on forest productivity. The simulation was done for 2 conifer plantations (Douglas fir, Pseudotsuga menziesii var. menziesii on the coast range of Washington state, USA; and loblolly pine, Pinus taeda on the Piedmont soils of Georgia) and a northern hardwood forest located in New Hampshire. Single applications of biosolids were given at 0, 5, 10, 20, and 40 Mg/ha, and multiple applications on 7 occasions at 3-yr intervals at rates of 5 and 10 Mg/ha. Highly significant increases in aboveground

phytomass and net primary productivity of Douglas fir plantations were obtained in a 100-yr simulation with increasing biosolids application rates. Results for loblolly pine from a 50-yr simulation produced about half the growth response of Douglas fir. Long-term simulations of northern hardwoods showed modest growth responses and small increases in NPP (net primary productivity) with added biosolids. The phytomass of one overstorey and 3 understorey species in the hardwood forest changed in response to different biosolids applications and varying species sensitivity to N supply. It is concluded that biosolids are a significant resource for enhancing forest productivity, particularly in conifer plantations. Estimates of N leaching losses from simulated forest sites combined with a literature review of leaching losses suggest that biosolids applications at 3-yr intervals with rates less than 8.5 Mg/ha (0.4 Mg N/ha) during active forest growth may pose little off-site contamination risk to ground water or surface waters.

OSU Link
Non-OSU Link

82. Marshall, V.G. and H.J. Barclay. 1994. Response of young Douglas-fir to urea fertilizer applied on and off snow. Forestry-Chronicle 70(3): 294-298.

Keywords: fertilization
growth

Abstract: The effects of 200 kg N ha-1 applied as urea fertilizer on 50 cm of snow or on bare ground were studied in an 11-year-old Douglas fir (Pseudotsuga menziesii) plantation on Vancouver Island. Core samples were taken from all trees on the plot 6 yr after treatment; height was measured for 20 selected dominant trees per plot 3 months and 4 yr after treatment. Up to 2 years following treatment, urea significantly increased absolute DBH increments over controls in all trees and the 20 selected trees per plot; response to fertilizer application on snow was equal to that on bare ground. Between the 3rd and 9th year following treatment, mean DBH increments were not significantly different for any treatment. Four-year absolute volume increments were 63 and 87% greater than the controls for bare-ground and on-snow applications, respectively.

OSU Link
Non-OSU Link

83. McLeod, A.A., R.C. Evans and R.K. Scagel. 1993. Conversion of understocked salal sites at Woss Lake, British Columbia. B.C. Ministry of Forests FRDA-Report 194. vi + 15 p.

Keywords: nursery operations
site preparation
mechanical preparation
fertilization
growth
tree/stand health
economics

Abstract: A trial comparing the effect of spot scarification and slow release NPK fertilizer application on stock types of coastal Douglas fir (Pseudotsuga menziesii) was conducted in a 25-year-old backlog site

occupied by a thick carpet of salal (Gaultheria shallon) in the CWHxm2 habitat of Vancouver Island, British Columbia. Bare root and container stock types were planted and treated, and mortality and growth were measured for 3 years. Despite the high fertilizer-related mortality of the bare-root stock type in the first year, the 3-year height growth performance of all treatments was better but more variable than that of the untreated seedlings. The value of site preparation and fertilizer for stimulating early growth varied by stock type. Bare-root stock did not respond strongly enough to fertilizer or site preparation to justify the cost of either of these treatments. Container stock types did not respond strongly enough to site preparation alone to justify the high cost of site preparation. The largest growth gains in the container stock types were associated with the combination of site preparation and fertilization.

OSU Link
Non-OSU Link

84. Mikels, R.A. 1983. Melamine, a controlled release fertilizer for conifer seedlings. Forestry-Abstracts 44(11): 698.

Keywords: fertilization
growth

OSU Link
Non-OSU Link

85. Miller, R.E. 1981. Response of Douglas-fir to foliar fertilization. *In* Proceedings: Forest Fertilization Conference, University of Washington, Seattle, Washington, USA. *Eds.* S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 62-68.

Keywords: fertilization
tree/stand health
growth
economics

Abstract: This paper summarizes past research about spray application of 10 to 32 percent nitrogen solutions to seedlings and established stands of Douglas-fir. These investigations establish that Douglas-fir and associated conifers can be foliarly fertilized with concentrated nitrogen solutions at dosages of 50 to 200 pounds per acre; however, fertilization with these solutions requires more critical selection of nitrogen source, dosage, additives, and, perhaps, time of year than does fertilization with urea prill. Some burning, up to about 30 percent of the needle surface, is visually disturbing but probably has no measurable effects on growth. With low dosages and careful application, gains in cubic volume or height growth per pound of applied nitrogen were similar for both spray and prill. Yet costs per pound of applied nitrogen have been about 25 percent more for 32 percent nitrogen solutions than for prilled urea. Hence, foliar application of concentrated nitrogen solutions is currently less cost effective than conventional use of urea solids for fertilizing Douglas-fir and associated conifers.

OSU Link
Non-OSU Link

86. Miller, R.E., M.V. Atherton and J.E. Wilcox. 1986. Comparative effects of three nitrogen fertilizers applied in fall and spring to a 29-year-old Douglas-fir plantation. Canadian-Journal-of-Forest-Research 16(5): 910-917.

Keywords: fertilization
growth
tree/stand health
tree physiology

Abstract: Stand growth and mortality were monitored for 13 yr after application of urea, ammonium nitrate or urea + ammonium sulphate (224 kg N/ha) in autumn 1967 and spring 1968 to plots in a 29-yr-old Douglas fir plantation on Vancouver Island, British Columbia. The treatments and a control were replicated 3 times. Foliar analysis indicated insufficient available N before treatment and an increase in available N 1 and 2 yr after fertilization. Addition of N at this location did not have a practical effect on stand growth and the field experiment was not sufficiently sensitive to detect real differences between N sources or season of application. Suggestions are included for improving field trials.

OSU Link
Non-OSU Link

87. Miller, R.E., G.W. Clendenen and D. Bruce. 1988. Volume growth and response to thinning and fertilizing of Douglas-fir stands in southwestern Oregon. Pacific-Northwest-Research-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-221. ii + 38 p.

Keywords: fertilization
thinning
growth

Abstract: Data were collected from 114 thinning (felling 15-80% of initial basal area) and/or fertilizer application (usually urea at 200 or 400 lb N/acre) trials in naturally regenerated Douglas fir (Pseudotsuga menziesii) stands in SW Oregon (111 stands) and N. California (3 stands). The data were used to develop regression equations to estimate volume growth for a 10-yr period of treated and untreated stands, aged 10-70 yr. The predictions for SW Oregon (SWOR) were compared with other growth predictions including DFSIM, a simulation model based on a broader, regional database. SWOR consistently showed greater gross and net growth of untreated Douglas fir and showed greater benefits of nitrogen fertilization, especially on poor quality sites and in young stands in the subregion than did DFSIM. SWOR predicted reduced gross volume growth during the 10 yr after thinning, faster recovery from early thinning on good than on poor sites, and increased wood production after nitrogen treatment in 70% of thinned and unthinned Douglas fir stands.

OSU Link
Non-OSU Link

88. Miller, R.E., J.W. Hazard and D.C. Young. 1991. Effects of foliar spray and prill applications of nitrogen fertilizer on four mixed-conifer stands. Forest-Science 37(3): 741-754.

Keywords: fertilization

growth
tree/stand health

Abstract: Concentrated urea-ammonium nitrate solution (32% N) and urea prill (granules; 46% N) were applied by helicopter at dosages of 56, 112, 224 and 448 kg N/ha before (5 May) and during (14 July) the 1969 growing season to four 40- to 70-year-old mixed stands of Pseudotsuga menziesii and Tsuga heterophylla near Sequim, Washington. Stand growth was measured repeatedly in the next 10 years. Helicopter application of both fertilizers was variable and therefore weakened comparisons between prill and foliar sprays and spring vs. summer applications. Applying 112 kg N/ha or more to these poor-site stands increased gross and net volume growth; volume growth was related linearly to N dosage of both prill and spray. Gains from prill apparently exceeded those from spray, but a subsampling of plots indicated that actual dosages, especially of spray, were less than target dosages. At the target dosage of 224 kg N/ha, 10-year gains in gross growth averaged 34.0 msuperscript 3/ha (30%) and 8.0 msuperscript 3/ha (7%) after prill and spray, respectively. Although fertilizer treatment accelerated tree losses, cumulative volume of dead trees was less than 15% of gross volume growth. Season of fertilization seemed to have no effect on efficiency of either prill or spray, but suspected differences between actual and target dosages may have influenced this comparison. Concentrated N solution applied at dosages up to about 224 kg N/ha caused little or no increase in foliar or tip damage. Doubling this conventional dosage and applying in the growing season, however, increased visible damage and may have reduced gains in volume growth.

OSU Link
Non-OSU Link

89. Miller, R.E., D.H. McNabb and J. Hazard. 1989. Predicting Douglas fir growth and response to nitrogen fertilization in western Oregon. Soil-Science-Society-of-America-Journal 53(5): 1552-1560.

Keywords: fertilization
growth
soil properties
stand conditions

Abstract: The objective of this study was to determine the efficacy of various stand (site index, age, and relative density), climatic (total precipitation, average daily solar radiation), site (elevation, soil depth, and available water-holding capacity), and soil-test variables (anaerobically mineralized N, total N, organic matter, and C:N ratio) to predict relative and absolute response of Pseudotsuga menziesii stands to a single application of 224 Kg/N ha as urea. The core equation with stand variables accounted for 70% of residual variation in average annual volume growth. Predicting response of fertilized stands proved much less precise. The best core equation explained 37% of the residual variation for average percentage response in volume growth and explained less variation in absolute response in both volume and basal area. Of the site, climatic, and soil-test variables, C:N ratio in the surface soil was the only one that significantly increased precision of the core equations. The best combined equation explained 46% of the variation in percent volume response. The anaerobic N mineralization test failed to make a significant contribution to the core equation and had a lower correlation with response than did the C:N ratio. Stand variables remain the most reliable predictors of fertilizer response in this region; any improvement from including soil data for N or organic matter is not justified because of their additional cost.

OSU Link
Non-OSU Link

90. Miller, R.E., E.L. Obermeyer and H.W. Anderson. 1999. Comparative effects of precommercial thinning, urea fertilizer, and red alder in a site II, coast Douglas-fir plantation. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-513.ii + 25 p.

Keywords: fertilization
thinning
precommercial thinning
growth
yield
tree/stand health
soil properties

Abstract: The number of red alder (Alnus rubra) trees retained with 300 Douglas-fir (Pseudotsuga menziesii) per acre was varied on a high-quality site in coastal Oregon. Alder densities of 0, 20, 40, and 80 per acre were tested. A fifth treatment eliminated nitrogen-fixing alder, but substituted nitrogen fertilizer. Treatment 6 had neither thinning nor alder control. Treatments were randomly assigned within each of three blocks in a 9-year-old plantation. Stand density was reduced within 15 of these 18 experimental units. Surplus conifers were cut, but surplus red alder were controlled by the "hack-and-squirt" method. Because numerous trees of other species regenerated naturally, combined density of all species before thinning ranged from 1400 to 5700 trees per acre. Subsequent 17-year change in number, average height, basal area, and volume of Douglas-fir were compared. Retaining 20, 40, or 80 alder per acre reduced numbers of associated Douglas-fir by about 10, 17, and 23 percent, respectively. In pure Douglas-fir plots, gross volume growth was similar for non-fertilized and fertilized plots, indicating no measurable benefits of additional nitrogen. In mixed stands, red alder reduced yield of associated Douglas-fir, but not yield of combined species. Similar comparisons are needed at other locations, especially those with known nitrogen deficiency.

OSU Link
Non-OSU Link

91. Miller, R.E., D.L. Reukema and J.W. Hazard. 1996. Ammonium nitrate, urea, and biuret fertilizers increase volume growth of 57-year-old Douglas-fir trees within a gradient of nitrogen deficiency. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-490. 12 p.

Keywords: planting operations
fertilization
growth

Abstract: Growth of dominant and codominant Pseudotsuga menziesii given 224 kg N/ha as ammonium nitrate, urea or biuret (a slow-release N source) in a N-deficient plantation in SW Washington was recorded over an 8-year period in relation to distance of the trees from a strip of the plantation interplanted with N-fixing Alnus rubra. Adjusted mean volume growth of the measured trees was increased by 22-28% on the east side of the mixed stand centreline and by 11-14% on the west side,

with no difference in response to the 3 fertilizers. Only biuret stimulated growth within the mixed strip of the stand. Biuret had no visible toxic effect on competing vegetation.

OSU Link
Non-OSU Link

92. Miller, R.E., J. Smith and H. Anderson. 2001. Detecting response of Douglas-fir plantations to urea fertilizer at three locations in the Oregon Coast Range. Pacific-Northwest-Research-Station,-USDA-Forest-Service Research-Paper PNW-RP-533. 20 p.

Keywords: fertilization
thinning
growth
tree/stand health

Abstract: Fertilizer trials in coast Douglas-fir (Pseudotsuga menziesii var. menziesii) in the Oregon Coast Range (USA) usually indicate small and statistically non-significant response to nitrogen (N) fertilizers. Inherently weak experimental designs of past trials could make them too insensitive to detect growth differences that actually exist. Ability to detect real differences among treatments should be improved by having more than two replications per treatment and by using covariance analysis to adjust observed treatment means for unequal starting conditions among experimental treatments. To demonstrate these assumptions, we used size at fertilizer application and a pre-fertilizer application (calibration) period of growth as covariates when analysing data from five coastal plantations at three locations: Toledo North, Toledo South and Bone Mountain. The trials had three to six replications per treatment and calibration periods of 6 or 7 years. Nitrogen fertilizer (urea at 200 lb N/acre) was assigned randomly to half the plots at each location when trees were 16 or 17 years old from seed. Our objectives were to quantify 4- or 7-year response to N fertilizer and to demonstrate practical means for detecting response. Effects of fertilizer application on tree diameter and height, and on basal area and volume growth per acre were estimated. Among the five non-thinned plantations, observed gross basal area growth was changed by -2 to 13% in the 4 or 7 years after fertilizer application. In the thinned portion of one plantation, there were few differences in response to fertilizer between thinned and unthinned plots. Observed responses were increased substantially by covariance analyses at some plantations but decreased at others. Random assignment of three to six plots per treatment did not ensure balanced or comparable plots for fertilized and non-fertilized treatments.

OSU Link
Non-OSU Link

93. Miller, R.E. and S.R. Webster. 1981. Fertilizer response in mature stands of Douglas-fir. *In* Proceedings: Forest Fertilization Conference, University of Washington, Seattle, Washington, USA. *Eds.* S.P. Gessel, R.M. Kenady and W.A. Atkinson. pp. 126-132.

Keywords: fertilization
growth
economics

Abstract: Published and unpublished response data from fertilizer trials in mature stands of Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) in western Washington and Oregon are examined. Stand age ranged from 60 to 120 years. It is concluded that: (1) nitrogen fertilization increased volume growth by 9 to 60 percent in these 60- to 120-year-old stands, (2) sizeable gains occurred in the first decade after fertilization, (d) the economics of high stumpage values and short investment periods make fertilizing mature Douglas-fir economically attractive.

OSU Link
Non-OSU Link

94. Mitchell, A.K., H.J. Barclay, H. Brix, D.F.W. Pollard, R. Benton and R. DeJong. 1996. Biomass and nutrient element dynamics in Douglas-fir: effects of thinning and nitrogen fertilization over 18 years. Canadian-Journal-of-Forest-Research 26(3): 376-388.

Keywords: fertilization
thinning
precommercial thinning
carbon allocation
tree physiology
growth
soil properties

Abstract: The effects of thinning (two-thirds of basal area removed) and N fertilizer (448 kg N/ha as urea) on biomass and nutrition of a 24-year-old Douglas fir (Pseudotsuga menziesii) stand at Shawnigan Lake, British Columbia, were studied over 18 years. At years 0, 9, and 18 after treatments, the aboveground biomass and N, P, K, Ca, and Mg contents of stemwood, stem bark, foliage, and dead and live branches were determined (kg/ha), and increments in these properties (kg/ha per year) were calculated for the 0-9 and 9-18 year periods. Foliar biomass was increased by both treatments during the first period and also by thinning in the second period. Aboveground net primary production (ANPP) per unit of foliage biomass (foliage efficiency) was increased by treatments in the 0-9 year period. The combined effects of increased foliage mass and foliage efficiency resulted in increased total biomass production. Thinning and fertilizer application increased the uptake of all elements except for P with fertilizer. This increase may have contributed to the long-term increase in stem growth. Retranslocation of elements before foliage shedding was important for tree nutrition, but was not improved by fertilizer during the 9-18 year measurement period. The efficiency of N use in dry matter production (ANPP/unit of N uptake) was decreased by fertilizer. This implied that poor sites would respond to fertilizer better than rich sites.

OSU Link
Non-OSU Link

95. Mitchell, A.K. and T.M. Hinckley. 1993. Effects of foliar nitrogen concentration on photosynthesis and water use efficiency in Douglas-fir. Tree-Physiology 12(4): 403-410.

Keywords: fertilization
tree physiology
photosynthesis

Abstract: Leaf-level physiological processes were studied in Douglas fir (Pseudotsuga menziesii) to determine whether apparent increases in stand-level water use efficiency (WUE) observed in response to nitrogen (N) fertilization were attributable to foliar N effects on carbon fixation rates or on stomatal control of water loss. Photosynthesis and transpiration were measured at different light intensities and ambient CO2 molar fractions and comparisons were made between current-year shoots with average foliar N concentrations of 1.58% (high-N) and 1.25% (low-N). Photosynthetic rates and foliar N concentrations were positively correlated. In response to light, photosynthesis and stomatal conductance were closely coupled and a similar coupling was observed in response to different ambient CO2 concentrations. Partitioning the photosynthetic responses into mesophyll and stomatal components indicated that foliar N altered mesophyll conductance but not stomatal control of water loss. High-N shoots had significantly greater rates of photosynthesis and transpiration than low-N shoots and, as a result, instantaneous WUE did not differ significantly between high-N and low-N shoots.

OSU Link
Non-OSU Link

96. Montigny, L.d. and S. Stearns-Smith. 2001. Douglas-fir fertilization with biosolids: five-year results at Whistler, B.C. B.C.-Ministry-of-Forests Extension-Note 50. 6 p.

Keywords: fertilization
growth
tree/stand health

Abstract: Biosolids (from municipal waste water treatment facilities) at 750, 1000, and 1500 kg-N/ha and conventional fertilizer at 225 kg-N/ha were applied in each of three seasons (spring, summer, and fall) to a 15-year-old B.C. coastal Douglas-fir (Pseudotsuga menziesii) plantation that had recently been precommercially thinned and pruned. Five-year results showed that rate and timing effects were independent. No height-growth response was evident, but annual diameter growth for all biosolids treatments averaged three times higher than for conventional fertilizer. Seasonal application differences were small but statistically significant. All plots, including the controls, experienced extensive top damage from snow and ice. Similar to growth, damage was greatest with biosolids fertilization. The study shows promise for biosolids fertilization as a viable alternative to conventional fertilization, but application in locations prone to snow and ice damage should be avoided.

OSU Link
Non-OSU Link

97. Nason, G.E., D.J. Pluth, R.T. Hardin and W.B. McGill. 1990. Dynamics of foliar N in Douglas-fir after spring and fall application of ammonium nitrate and urea. Canadian-Journal-of-Forest-Research 20(9): 1515-1523.

Keywords: fertilization
tree physiology

Abstract: Foliar N dynamics were studied from 1982 to 1984 after spring or autumn application of ammonium nitrate or urea at 200 kg N/ha to an intermediate-productivity 38-yr-old Douglas fir (Pseudotsuga menziesii) stand growing on Humo-Ferric Podzols onVancouver Island, British Columbia.

Douglas fir responded by increasing the N concentration of existing foliage, and both the concentration and content of N in new shoots. Six months after spring fertilization, N concentration in current foliage averaged 30 and 21% above that of the control for ammonium nitrate and urea, respectively. N concentration of current foliage was increased after 2 years in the ammonium nitrate treatment only. When ammonium nitrate was applied in autumn, peak N concentration in current foliage occurred after 6 months (in mid-spring), at 25% above that of the control. Autumn application urea did not affect current foliage N concentration until the next autumn, when a 19% increase over that of the control was observed. In the first autumn after fertilization (seasons of application combined), ammonium nitrate caused a 26% increase over control in N content of current foliage, whereas urea caused a 13% increase. This superiority of ammonium nitrate over urea was attributed to the nitrate ion.

OSU Link
Non-OSU Link

98. Nason, G.E., D.J. Pluth and W.B. McGill. 1988. Volatilization and foliar recapture of ammonia following spring and fall application of nitrogen-15 urea to a Douglas-fir ecosystem. Soil-Science-Society-of-America-Journal 52(3): 821-828.

Keywords: fertilization
tree physiology
soil properties

Abstract: Seasonal effects on the volatilization and vegetal recapture of NH3 following application of pelleted 15N urea at 200 kg N ha-1 to a 40-yr-old Douglas-fir [Pseudotsuga menziesii] ecosystem were investigated. Volatilization totalled 14 and 0.7% of applied N in spring and autumn, respectively, and the difference appeared to be related to precipitation patterns following fertilization. Volatilization was generally enhanced by small spring rainfalls while depressed by larger autumn rains. The isotopic abundance of evolved NH3 fluctuated from >90 to <10% of that of the fertilizer source. These fluctuations reflected the role of precipitation in the regulation of spatial heterogeneity of urea and urease in soil. Under spring conditions NH3 was recaptured by potted Douglas-fir seedlings. Seedlings at 10 cm above the forest floor captured 16 times as much NH3 as seedlings positioned at the 150-cm elevation. Labelled N was distributed among seedling tissues in the order: current foliage > 1-year-old foliage > roots which is consistent with anabolic incorporation and translocation. This mechanism may have a significant role in plant nutrition when conditions favourable to NH3 volatilization follow urea fertilization.

OSU Link
Non-OSU Link

99. Nelson, E.E. 1989. Black bears prefer urea-fertilized trees. Western-Journal-of-Applied-Forestry 4(1): 13-15.

Keywords: fertilization
tree/stand health

Abstract: Feeding damage by the black bear (Ursus americanus) to urea-fertilized 25-yr-old Douglas fir (Pseudotsuga menziesii) in the Mount Hood National Forest, Oregon, resulted in tree mortality 4x as

severe as among unfertilized trees. Damage was most apparent following application of urea at 448 kg N/ha in 1972, and 224 kg N/ha in 1977. Only Douglas fir, the dominant species in the stand, was attacked (western hemlock (Tsuga heterophylla), western red cedar (Thuja plicata) and red alder (Alnus rubra) were scattered through the stand). Attacked trees were somewhat larger than the stand average but the difference was not significant. Bears appeared to be attracted to the more vigorous trees, which were on fertilized plots.

OSU Link
Non-OSU Link

100. Nelson, E.E., M.G. McWilliams and W.G. Thies. 1994. Mortality and growth of urea-fertilized Douglas-fir on a Phellinus weirii-infested site in Oregon. Western-Journal-of-Applied-Forestry 9(2): 52-56.

Keywords: planting operations
fertilization
tree/stand protection
growth
tree/stand health
soil properties

Abstract: Twelve plots were established in 1972 in an 11-yr-old Douglas fir (Pseudotsuga menziesii) plantation infected with Phellinus weirii, the cause of laminated root rot. All plots were thinned and either interplanted with red alder (Alnus rubra) or fertilized at 5- to 10-yr intervals with urea to determine the effect of nitrogen on tree growth and mortality caused by P. weirii, or left untreated. Interplanted alder, however, failed to survive. Mortality was assessed at intervals of 2 to 3 yr. Plots were inventoried (100% cruise) in 1978 and 1990. Growth over 12 yr appeared better on fertilized than nonfertilized plots, but the difference was not significant. Mortality caused by the preferential feeding of black bears [Ursus americanus] on the inner bark of fertilized trees reduced the overall gain. Mortality caused by laminated root rot did not differ significantly among treatments. Three months after the initial application of urea at 448 kg N/ha, soil sampled to a depth of 30 cm was higher in ammonium and nitrate forms of nitrogen on fertilized than nonfertilized plots, but increases were not significant. Numbers of soil bacteria were directly correlated with soil ammonium content (P = 0.1092). Numbers of aerobic actinomycetes were inversely correlated with soil nitrate content (P = 0.0398).

OSU Link
Non-OSU Link

101. Omule, S.A.Y. 1990. Net basal area response 9 years after fertilizing thinned and unthinned Douglas-fir. B.C. Ministry of Forests FRDA-Report 097. vi + 20 p.

Keywords: fertilization
thinning
growth

Abstract: Equations were developed to estimate net basal area response of Douglas fir (Pseudotsuga menziesii) to nitrogen (urea) fertilizer in terms of initial stand attributes, based on remeasurement data over a 9-yr period from 176 plots on Vancouver Island, British Columbia.

OSU Link
Non-OSU Link

102. Peterson, C.E. 1984. Fertilization of Douglas-fir plantations in the Pacific Northwest RFNRP Cooperative. *In* Proceedings IUFRO Symposium on Site and Productivity of Fast Growing Plantations Volume 2, South African Forest Research Institute, Pretoria, South Africa. Eds. D.C. Grey, A.P.G. Schonau and C.J. Schutz. pp. 637-645.

Keywords: planting operations
fertilization
thinning
precommercial thinning
growth

Abstract: Since 1975, the RFNRP cooperative has established 26 installations in young widely spaced plantations of Douglas-fir for testing response to 224 kg-N/ha. These plantations ranged in breast-height age from 3 to 23 years, and although response to fertilization was favorable in all Douglas-fir plantations, those which were spaced to 1000 trees/ha responded significantly better than plantations of 725 trees/ha, in both absolute and relative 2-year basal area increment (msuperscript 2 ha-1 year-1). Response also appears to be greater when fertilizer was applied 2 years after precommercial thinning, as opposed to fertilizing and thinning at the same time. The relationship of growth response with stocking level is discussed, as well as the timing of fertilization relative to spacing, in young Douglas-fir plantations.

OSU Link
Non-OSU Link

103. Peterson, C.E. and J.W. Hazard. 1990. Regional variation in growth response of coastal Douglas-fir to nitrogen fertilizer in the Pacific Northwest. Forest-Science 36(3): 625-640.

Keywords: fertilization
thinning
growth

Abstract: Hypothesis-testing for differences in growth responses among physiographic strata, thinning levels, and fertilizer dosage levels resulted in a set of empirical models for predicting the volume increment response of even-aged coastal Douglas fir (Pseudotsuga menziesii) in W. Washington and Oregon to N fertilizer treatment. Absolute and percentage responses are estimated for both thinned and unthinned stands as a function of dosage levels and physiographic provinces. Although not 'highly' significant, the physiographic factor was retained in the models for purposes of refinement.

OSU Link
Non-OSU Link

104. Peterson, C.E., P.J. Ryan and S.P. Gessel. 1984. Response of northwest Douglas-fir stands to urea: correlations with forest soil properties. Soil-Science-Society-of-America-Journal 48(1): 162-169.

Keywords: fertilization
thinning
growth
soil properties

Abstract: Replicated forest floor and surface soil (0-15 cm) samples were obtained from control plots at 160 field installations in western Washington and Oregon. Six-year growth responses of thinned and unthinned Douglas-fir [Pseudotsuga menziesii] treated with 0, 224, and 448 of urea-N ha-1 were correlated with 18 forest floor and surface soil properties of the control plots. Forest floor nitrogen properties were the most highly correlated with various estimates of response in both thinned and unthinned stands; these correlations were generally independent of methods used to estimate response. For unthinned stands, C/N ratios of both forest floor and surface soil were well correlated with growth response to fertilizer, whereas for thinned stands, N content (kilograms per hectare) of the forest floor was consistently correlated with response.

OSU Link
Non-OSU Link

105. Prescott, C.E. 1995. Does nitrogen availability control rates of litter decomposition in forests? Plant-and-Soil 168/169: 83-88.

Keywords: fertilization
soil properties

Abstract: The effects of increased exogenous N availability on rates of litter decomposition were assessed in several field fertilization trials. In a jack pine (Pinus banksiana) forest, needle litter decomposed at the same rate in the controls and those plots fertilized with urea and NH4NO3 at 1350 kg N/ha (+or-P and K). Mixed needle litter of western hemlock (Tsuga heterophylla), western red cedar (Thuja plicata), and Douglas-fir (Pseudotsuga menziesii) from plots amended with sewage sludge (500 kg N/ha) lost less weight than the controls.Forest floor material also decomposed more slowly after amendment with sewage sludge. Paper birch (Betula papyrifera) leaf litter treated with either sewage sludge (1000 kg N/ha), pulp sludge, or a sewage/pulp sludge-mixture decomposed at the same rate as the controls. Exogenous N availability therefore had little impact on litter decomposition rates. The influence of endogenous N availability on litter decomposition rates was studied with a microcosm. Lodgepole pine (Pinus contorta var. latifolia) needle litter collected from trees fertilized at 525 kg NH4NO3-N/ha and green needles were both richer in N (1.56 and 1.9% N, resp.) than needles from control trees (0.33 and 0.88% N, resp.), although all the needles decomposed at the same rate. It was concluded that N availability alone, either exogenous or endogenous, did not control litter decomposition rates. Increased N availability, through fertilization or deposition, in the absence of changes in vegetation composition, was not considered sufficient to alter rates of litter decomposition in forests.

Non-OSU Link

106. Prescott, C.E., L.P. Coward, G.F. Weetman and S.P. Gessel. 1993a. Effects of repeated nitrogen fertilization on the ericaceous shrub, salal (Gaultheria shallon), in two coastal Douglas-fir forests. Forest-Ecology-and-Management 61(1-2): 45-60.

Keywords: fertilization
growth
stand conditions

Abstract: Understorey vegetation changes were quantified following nitrogen fertilizer trials at two sites in the Pacific Northwest. In the Pack Forest, Washington, USA, - second growth (70-yr-old) Douglas fir (Pseudotsuga menziesii) - salal (Gaultheria shallon) was eliminated in a plot that had been fertilized with nitrogen alone (1540 kg N/ha as ammonium nitrate and urea between 1950 and 1982), but was unchanged in a plot that received phosphorus and sulfur in addition to nitrogen (1082 kg N/ha). In a trial near Parksville, Vancouver Island - logged in 1947, stand comprising 75% Douglas fir, site index 33 m at age 50 yr - salal cover was reduced with increasing amounts of nitrogen, and was eliminated in plots that received 600 kg N/ha as urea in three applications. Reductions were less pronounced in plots that received sulphur in addition to nitrogen. In the Pack Forest trial, the cover of snowberry (Symphoricarpos albus) increased in the plot where salal was eliminated; in the Parksville trial, no other species became more abundant in the absence of salal. Tree stem volume and stem volume increment in each plot were not related to salal cover in the plots. Results suggest that high concentrations of ammonium and nitrate in the forest floors of N-fertilized plots may render salal less competitive, or may interfere with ericoid mycorrhizae, contributing to reduced cover of salal in forests receiving repeated N-applications.

107. Prescott, C.E., M.A. McDonald, S.P. Gessel and J.P. Kimmins. 1993b. Long-term effects of sewage sludge and inorganic fertilizers on nutrient turnover in litter in a coastal Douglas fir forest. Forest-Ecology-and-Management 59(1-2): 149-164.

Keywords: fertilization
soil properties

Abstract: Rates of litter input, decomposition, net N mineralization, and N and P supply on the forest floor were measured in a 70-yr-old second growth stand of Douglas fir (Pseudotsuga menziesii) on a poor site in western Washington state, approximately 10 yr after applications of sewage sludge and inorganic fertilizers. Sewage sludge was applied to three plots at the rate of 6000 kg N/ha, and nitrogenous fertilizers were applied to two plots at rates of 1082 and 1568 kg N/ha. The rate of each process in each treated plot was compared with that in an adjacent control plot. Amounts of N returned in needle litter during 1 yr were greater on sludged and fertilized plots relative to adjacent control plots. Decomposition of a standard needle litter was the same on all plots after a 2-h in situ incubation. Rates of N mineralization during aerobic incubations of forest floor material were similar in all plots in field incubations, but smaller rates were measured in material from sludged plots in laboratory incubations. Greenhouse bioassays with Douglas fir and Sitka spruce (Picea sitchensis) seedlings showed greater P supply in forest floor material from sludged plots, but no differences in N supply between any treatments. Turnover of N in litter was not different 10 yr after fertilization of this forest with sewage

sludge or N fertilizer. There was evidence of long-term enhancement of P turnover in litter plots treated with sewage sludge.

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108. Prescott, C.E. and L.M. Zabek. 1999. Decomposition and nitrogen mineralization in forests of British Columbia: effects of forest management practices. *In* Proceedings: Pacific Northwest forest and rangeland soil organism symposium; 1998 March 17-19; Corvallis,OR. Pacific-Northwest-Research-Station, USDA-Forest-Service General-Technical-Report PNW-GTR-461. *Eds.* R.T. Meurisse, W.G. Ypsilantis, and C. Seybold. 124-136 pp.

Keywords: planting operations
fertilization
soil properties

Abstract: The productivity of most forests in the Pacific Northwest is limited by the availability of nitrogen. Nitrogen availability is largely controlled by the rate at which N is recycled from organic matter, through the processes of decomposition and mineralization. These processes are controlled by the factors that limit the activities of the soil organisms involved, particularly temperature, moisture, and the physical and chemical nature of the organic matter. Forest management activities may influence each of these factors and thereby affect rates of decomposition, N mineralization and N availability. The influences of several common forest management activities on decomposition and N mineralization were examined in a suite of experiments across British Columbia, Canada. Rates of decomposition were compared in forests and adjacent clear felled areas at 22 sites, and rates were either the same or slower in the felled areas. Several sites had additional silvicultural treatments that provide a range of either opening size or removal intensity. Decomposition rates were not influenced by opening size, but rates of net N mineralization and nitrification were increased in openings greater than 0.1 ha. Tree species influences N mineralization in the forest floor, with highest rates occurring in Douglas-fir and broadleaf species and lowest rates in cedar and pines. The decomposition rates of foliar litters was best predicted by its lignin concentration. The influence of managing to maintain a component of broadleaf species was examined in decomposition experiments with pure and mixed litter of aspen and spruce, Douglas-fir and alder, and lodgepole pine, Douglas-fir and paper birch. There was no effect of mixing litters on their rates of decomposition. Likewise, N fertilization had no effect on decomposition rates in trials in coastal Douglas-fir and aspen.

OSU Link
Non-OSU Link

109. Preston, C.M., V.G. Marshall, K. McCullough and P.J. Mead. 1990. Fate of 15N-labelled fertilizer applied on snow at two forest sites in British Columbia. Canadian-Journal-of-Forest-Research 20(10): 1583-1592.

Keywords: fertilization
soil properties

Abstract: Fertilizer was applied on snow in January 1981 at 100 kg N/ha as (15N)urea, 15NH4NO3 or NH415NO3 to 11-yr-old lodgepole pine (Pinus contorta var. latifolia) at Spillimacheen in the British Columbia interior and as (15N)urea (200 kg N/ha) to 13-yr-old Douglas fir (Pseudotsuga menziesii) at Green Mountain, a coastal site in British Columbia. Recovery of labelled N after one growing season was determined in soil and biomass at both sites, and it was also monitored during the growing season in snow and soil at Spillimacheen. At Green Mountain, 5.5% of urea N was recovered in tree biomass, 10.8% in understorey and 33.4% in soil organic N (total recovery 49.7%). Leaching may have contributed to N losses at Green Mountain, but was probably not a direct consequence of the application on snow. At Spillimacheen, total recovery of (15N)urea was 93.3%, with 10.1% in tree biomass, 2.4% in understorey and 80.8% in soil. For 15NH4NO3, recoveries were 5.3% in tree biomass, 2.9% in understorey and 87.0% in soil, for a total of 95.2%. For NH415NO3, recoveries were 1.9% in tree biomass, 3.4% in understorey and 39.1% in soil, for a total of 44.4%. At Spillimacheen, the performance of 15NH4NO3 was comparable to that of urea in tree uptake and soil retention. There were large losses with the NH415NO3 source, however, probably because of leaching and denitrification during snowmelt. For this reason, fertilization with nitrate on snow is not recommended because of nitrate's susceptibility to leaching, but urea and ammonium sources may be applied under these conditions.

110. Preston, C.M. and R.H. Newman. 1995. A long-term effect of N fertilization on the 13C CPMAS NMR of de-ashed soil humin in second-growth Douglas-fir stand of coastal British Columbia. Geoderma 68(4): 229-241.

Keywords: fertilization
thinning
soil properties

Abstract: Carbon-13 CPMAS NMR spectroscopy was used to examine long-term effects of thinning and N fertilization on the humin fraction of soil organic matter in a second-growth Douglas-fir (Pseudotsuga menziesii) stand in coastal British Columbia, Canada. De-ashed OM-enriched humin fractions were prepared from three mineral soil horizons of four silvicultural treatments using 1.0M HF accompanied by removal of ferromagnetic iron particles, and a density separation. With some exceptions a higher proportion of mass was recovered in the denser, light-coloured fraction, and a higher proportion of C and N in the less-dense, dark fraction. In all cases, the less-dense fraction was enriched in total C compared to the original crude humin, and had a more favourable C:Fe ratio for NMR spectroscopy. The fraction of observable C was 33-37% for 8 of the samples, but as low as 7.6% for the remaining four. Carbon-13 CPMAS NMR spectra had typical features for humins (alkyl C, O-alkyl C, di-O-alkyl C, aromatic C, and carboxyl, ester and amide C). With fertilization, there was a small but consistent decrease in the ratio of alkyl to O-alkyl C, regardless of horizon or thinning, indicating a lower extent of decomposition. Carbon-13 subspectra based on proton spin relaxation time (T1(1H)) were obtained for one fertilized and one unfertilized sample. Subspectra of the slowly-relaxing (long T1(1H)) domain were dominated by long-chain alkyl C. For the fertilized sample, the subspectrum of the fast-relaxing (short T1(1H)) domain had a higher proportion of O- and di-O-alkyl C, consistent with results from the normal CPMAS NMR spectra. Despite the uncertainties introduced by the de-ashing treatment and the low fraction of observable C, 13C CPMAS NMR showed that fertilization has a long-term effect which is reflected in this humin fraction.

OSU Link
Non-OSU Link

111. Prietzel, J., G.L. Wagoner and R.B. Harrison. 2004. Long-term effects of repeated urea fertilization in Douglas-fir stands on forest floor nitrogen pools and nitrogen mineralization. Forest-Ecology-and-Management 193(3): 413-426.

Keywords: fertilization
soil properties

Abstract: In six Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] stands in the Puget Sound Region in Western Washington/USA, forest floor C and N pools were quantified on control plots and on plots that had been fertilized repeatedly with urea 8-30 years ago (total amount of applied N 0.9-1.1 Mg ha-1). Additionally, net N mineralization and nitrification rates were assessed in field and laboratory incubation experiments. Forest floor C/N ratios were decreased on the fertilized plots of all sites compared to the respective control plots. The decreases were particularly strong at sites with initial C/N ratios larger than 30. On sites with low productivity (site index at age 50: <33 m), N fertilization resulted in considerable increases in forest floor N pools. Net N mineralization and nitrification during 12-week field incubation was negligible for the unfertilized and fertilized plots of all except one site (Pack Forest), where the stand had been clear-cut 2 years ago. The increases in N mineralization rates during 12-week laboratory incubation induced by repeated N fertilization showed an inverse relationship to the time elapsed since the last fertilizer application, and were generally larger at sites with initial forest floor C/N ratios >30. For the investigated sites, fertilization effects on net N mineralization sustained for at least 11 years after the last fertilizer application. Nitrification correlated strongly with the forest floor pH; significant formation of NO3- was observed only for O layers with a pH (H2O) higher than 4.5.

OSU Link
Non-OSU Link

112. Radwan, M.A. and J.S. Shumway. 1984. Site index and selected soil properties in relation to response of Douglas-fir and western hemlock to nitrogen fertilizer. *In* Forest soils and treatment impacts: Proceedings of the Sixth North American Forest Soils Conference, Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN, June 1983. *Ed.* E.L. Stone. pp. 89-104.

Keywords: fertilization
growth
soil properties

Abstract: Studies were made in 25 Douglas fir stands in Washington and Oregon and in 16 western hemlock stands in Washington. Site index, total and mineralizable soil N were the only variables correlated with growth response to N fertilizer by Douglas fir. Growth response of hemlock was correlated with extractable P/total N in the soil. Total N and mineralizable S in mineral soil were highly correlated and showed moderate negative correlations with growth response of hemlock, but site index was not correlated with response. Results suggest that site index and soil N seem promising indicators of the response of Douglas fir to N fertilizer, while extractable P and the P/N ratio may indicate the response of hemlock. Soil N appears to be more important than soil P in predicting the response of

Douglas fir on the sites studied. Soil S did not appear to limit the response of either species to N fertilizer and does not seem promising for estimating the response to N.

OSU Link
Non-OSU Link

113. Radwan, M.A., J.S. Shumway, D.S. DeBell and J.M. Kraft. 1991. Variance in response of pole-size trees and seedlings of Douglas-fir and western hemlock to nitrogen and phosphorus fertilizers. Canadian-Journal-of-Forest-Research 21(10): 1431-1438.

Keywords: nursery operations
nursery fertilization
fertilization
tree physiology
growth

Abstract: A study was made of the effects of N, P and NP fertilizer treatments on plant nutrients and growth of Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla). Three trials were conducted, (1) and (2) on pole-size trees at two different sites inWashington and (3) on potted seedlings in a lathhouse; only T. heterophylla was studied in (2). Soil series were Bunker for Douglas fir and Klone for western hemlock in trials 1 and 3, and Vesta in trial 2. Nitrogen fertilizers used were urea in trial 1 and ammonium nitrate in the other two trials; P was applied as triple superphosphate in all three trials. For each species in trial (1), P was applied at 0, 100, 300 and 500 kg P/ha and N was applied at 0 and 224 kg N/ha in a factorial design. In trial (2), P was applied at 0, 100 and 300 kg P/ha and N was applied at 0 and 112 kg N/ha in a factorial design. In trial (3), N and P were applied individually to seedlings at a rate of 100 kg N/ha and 226 kg P/ha. In general, fertilizer treatments changed the levels of some plant-tissue nutrients of the pole-size trees and potted seedlings. Neither height nor basal area growth of the trees were significantly affected by any of the treatments in the first two trials. Seedling growth of both Douglas fir and western hemlock was improved by P fertilizer, but was negatively affected by N fertilizer. The results clearly show differences between pole-size trees and seedlings in response to N and P fertilizers. It is concluded that N should not be applied where soils are high in N and low in P, and that P applications should be confined to sites with low-P soils, when trees are young, before canopy closure.

OSU Link
Non-OSU Link

114. Rollwagen, B.A. 1983. Effects of ammonium and nitrate application on rhizosphere pH, growth and nutrient uptake by Douglas-fir, Sitka spruce and western hemlock. Forestry-Abstracts 44(11): 699.

Keywords: fertilization
soil properties
growth
tree physiology

OSU Link
Non-OSU Link

115. Rose, R., M. Atkinson, J. Gleason and T. Sabin. 1991. Root volume as a grading criterion to improve field performance of Douglas fir seedlings. New-Forests 5(3): 195-209.

Keywords: nursery operations
fertilization
tree/stand health
growth

Abstract: Three Oregon seed sources of Douglas fir (Pseudotsuga menziesii) were grown as 2+0 bare-root seedlings, and graded into three root-volume categories (<9, 9-13, and >13 cmsuperscript 3) before outplanting in Columbia County, Oregon in January 1987. The following were assessed: (1) differences in survival and growth after one and two growing seasons in the field; (2) relation(s) of seedling height after one and two seasons to preplanting nursery root volume, total fresh weight, root-collar diameter, and height; and (3) differences in field performance due to application of NPK fertilizer at planting. Field survival was >90% among all root-volume categories. Seedlings in the largest category grew significantly better than those in the two smaller categories over two seasons. Fertilization at time of planting had no effect on survival or growth because of shallow placement (3 cm below soil surface) of the fertilizer pellet. The results suggest that using root volume as well as height and diameter as a seedling grading parameter is worthwhile where morphological quality must be maximized to improve field performance.

OSU Link
Non-OSU Link

116. Rose, R. and J.S. Ketchum. 1998. Early results of the 'Herb II' study: evaluating the influence vegetation control has on fertilization at the time of planting. *In* Proceedings of the Annual Meeting of the Western Society of Weed Science, Waikoloa, Hawaii, 10-12 March, 1998. pp. 55-59.

Keywords: release treatments
chemical release
fertilization
growth

Abstract: Field trials were conducted at 5 sites in the Pacific Northwest region of the USA to assess the interactive effects between increasing levels of control of deerbrush (Ceanothus integerrimus), snowbrush (C. velutinus), black cottonwood (Populus trichocarpa), Scotch broom (Cytisus scoparius), Portuguese broom (C. striatus), trailing blackberry (Rubus sp.), thimbleberry (R. parviflorus) and salmonberry (R. spectabilis) with hexazinone or sulfometuron, and fertilizer treatments using slow release briquettes of N:P:K at 14:3:3 or 9:9:4 applied at planting for Douglas fir (Pseudotsuga menziesii), ponderosa pine (Pinus ponderosa), western hemlock (Tsuga heterophylla) and coastal redwood (Sequoia sempervirens). Results indicated that at all but one site, weed control +or- fertilizer led to increased tree growth, while at the fifth site weed control + fertilizer gave the greatest growth. Fertilizer alone did not increase growth at any site.

Non-OSU Link

117. Rose, R. and J.S. Ketchum. 2002. Interaction of vegetation control and fertilization on conifer species across the Pacific Northwest. Canadian-Journal-of-Forest-Research 32(1): 136-152.

Keywords: fertilization
release treatments
chemical release
growth
tree/stand health
tree physiology
stand conditions

Abstract: An experiment evaluating three levels of vegetation competition control (no control, 1.5 m2 of vegetation control, and 3.3 m2 of vegetation control), each with two fertilizer application treatments (fertilizer application at the time of planting with complete slow-release fertilizer (WoodaceReg. IBDU), or no fertilizer application), was installed at five sites. Two of these sites were planted with Douglas-fir (Pseudotsuga menziesii) in the Oregon Coast Range, one with ponderosa pine (Pinus ponderosa) in eastern Washington, one with western hemlock (Tsuga heterophylla) in the coastal hemlock zone in Oregon, and one with coastal redwood (Sequoia sempervirens) in northern California, USA. At four of the five sites, mean stem volume, basal diameter, and height of seedlings increased significantly with increasing area of weed control, and the magnitude of difference between treatments increased with time. Fertilizer application significantly increased seedling size only at the two sites with adequate soil moisture; increases were marginally significant at a third. Response to fertilizer application was less than from weed control and impacted growth for only the first year, whereas the influence of weed control continued to influence growth the entire length of the study (4 years). Area of vegetation control and fertilizer application did not interact significantly at any site.

OSU Link
Non-OSU Link

118. Rose, R. and J.S. Ketchum. 2003. Interaction of initial seedling diameter, fertilization and weed control on Douglas-fir growth over the first four years after planting. Annals-of-Forest-Science 60(7): 625-635.

Keywords: nursery operations
fertilization
release treatments
chemical release
growth
tree/stand health
stand conditions

Abstract: Planting larger stock, fertilizer application and added years of weed control are often employed to increase growth rate of plantations. We evaluated these techniques using a replicated factorial study design repeated in two diverse locations in western Washington State, USA. Two different sizes of planting stock, NPK fertilizer application at planting and in the following year, and two or three years of weed control using herbicides were tested. No significant interactions among the treatment levels were found with all treatments influencing Douglas-fir (Pseudotsuga menziesii) growth in an additive manner. Fourth year stem volume gains were greatest from planting larger initial stock: planting seedlings 2 mm larger in basal diameter resulted in fourth-year stem volume gains of 35 and 43%. The fertilizer application treatments used produced early gains, but they were short lived. The

third-year weed control treatment had no observable effect on fourth-year stem volume or on volume growth in years three or four.

OSU Link
Non-OSU Link

119. Rosso, P. and E. Hansen. 1998. Tree vigour and the susceptibility of Douglas fir to Armillaria root disease. European-Journal-of-Forest-Pathology 28(1): 43-52.

Keywords: fertilization
thinning
pruning
tree/stand protection
growth
tree/stand health
carbon allocation

Abstract: The effects of thinning, fertilization and pruning on the vigour of Douglas fir (Pseudotsuga menziesii) and its susceptibility to Armillaria root disease were investigated in Oregon, USA. Tree vigour was defined as the relative capacity for tree growth, expressed as the above-ground biomass increment per unit of photosynthetic tissue, or growth efficiency (GE). It has been hypothesized that trees with higher GE can better resist pathogen attack, and that GE can be used as a predictor of tree susceptibility to disease. In a previous study, four P. menziesii plantations were thinned, fertilized and pruned in all combinations, and the effects of these treatments on tree vigour were measured after 10 years. Root disease was not a factor in the initial study design, and mortality was ignored until 8 years after the treatments were applied. The results of an earlier study were utilized and the correlation between Armillaria root disease incidence and the effects of earlier stand treatments on tree growth was investigated. A. ostoyae [A. obscura] was the primary cause of mortality in the study area. The disease incidence of infected subplots ranged from 2 to 20%. A. obscura incidence was the highest at medium tree density (6.1%), slightly lower on the low density (5.6%) and lowest on the unthinned plots (3.8%). There were no significant correlations between disease incidence and previous tree growth. The vigour of trees that became symptomatic or died by 1993 was not significantly different from the vigour of trees that remained asymptomatic in 1983-85. On these sites, in areas of infection, A. obscura was causing mortality of the largest, fastest growing trees, as well as less vigorous trees. It is concluded that Armillaria continues to cause mortality, regardless of the growth efficiency or growth rate of the host.

OSU Link
Non-OSU Link

120. Roth, B.E. and M. Newton. 1996a. Role of Lammas growth in recovery of Douglas-fir seedlings from deer browsing, as influenced by weed control, fertilization, and seed source. Canadian-Journal-of-Forest-Research 26(6): 936-944.

Keywords: planting operations
release treatments
chemical release
fertilization

tree/stand protection
growth
tree/stand health

Abstract: This study examined the effects of weed control, nitrogen fertilizer, and seed source on Lammas growth (second flushing) in Douglas fir (Pseudotsuga menziesii) seedlings on 3 sites in the Oregon Coast Range. It also assessed the occurrence of deer (Odocoileus hemionus columbianus) browsing as related to these silvicultural treatments and examined the role of Lammas growth in seedling recovery and escape from deer browsing. Seedlings (averaging 54 cm tall, 6 mm diameter at 15 cm above ground) were planted in February 1992, and measured at the time of planting and in autumn 1992 and 1993. Complete weed control with hexazinone (annual applications + spot treatments as necessary) significantly increased the occurrence of Lammas growth. Nitrogen fertilizer (220 kg/ha urea) decreased Lammas growth significantly, at least in part by favouring weed growth. Lammas growth was not influenced by seed source (genetically improved from a seed orchard or local wild stock). The increased Lammas growth associated with weed control mediated the effects of deer browsing. Although multiple-year browsing occurred more commonly on weeded than unweeded seedlings, after two growing seasons weeded seedlings that were repeatedly browsed were twice as large as unbrowsed, unweeded seedlings. On one site, stock of wild origin was more heavily browsed than that from a seed orchard.

OSU Link
Non-OSU Link

121. Roth, B.E. and M. Newton. 1996b. Survival and growth of Douglas-fir relating to weeding, fertilization, and seed source. Western-Journal-of-Applied-Forestry 11(2): 62-69.

Keywords: planting operations
fertilization
release treatments
chemical release
growth
tree physiology
tree morphology
tree/stand health

Abstract: The goal of this study was to quantitatively evaluate the individual and interactive effects of weed control, nitrogen fertilizer, and seed source on Douglas fir (Pseudotsuga menziesii) survival and growth in plantations on a range of sites and growing conditions in western Oregon. Weed control with hexazinone (broadcast application after planting) was the dominant factor influencing seedling survival and growth and accounted for 49% of the explained variation in seedling volume after 2 years. Nitrogen fertilizer (urea) had no effect when used in conjunction with weed control and a negative effect when used without weed control. Seedlings from a seed orchard source were significantly larger in diameter and volume than those from a wild local source after two growing seasons, but second-year heights were similar for the two seedling types. Initial seedling size was positively correlated with growth rate.

OSU Link
Non-OSU Link

122. Sachs, D. and J.A. Trofymow. 1991. Testing the performance of FORCYTE-11 against results from the Shawnigan Lake thinning and fertilization trials on Douglas-fir. Canadian-Forest-Service, Pacific and Yukon Region Information-Report BC-X-324. viii + 58 p.

Keywords: fertilization
thinning
precommercial thinning
growth
yield
tree physiology
carbon allocation
tree/stand health
computer modeling

Abstract: FORCYTE-11 is an ecosystem-based forest growth simulation model. Its performance was evaluated with data on stand and tree biomass, height, stocking (mortality) and foliar assimilation and loss rates for Douglas fir (Pseudotsuga menziesii) in thinning/fertilizer trials in British Columbia.

OSU Link
Non-OSU Link

123. Shumway, J.S. and H.N. Chappell. 1995. Preliminary DRIS norms for coastal Douglas-fir soils in Washington and Oregon. Canadian-Journal-of-Forest-Research 25(2): 208-214.

Keywords: fertilization
thinning
growth
soil properties

Abstract: The Diagnosis and Recommendation Integrated System (DRIS) has been used successfully to evaluate interactions between nutrients and fertilizer response and for diagnosing nutrient deficiency in agricultural crops. This study used soil tests to develop DRIS norms and evaluate their effectiveness in coastal Douglas fir (Pseudotsuga menziesii) forests. DRIS norms for nitrogen, phosphorus, potassium, and calcium were developed using soil test and site index data from 72 soil series that commonly support Douglas fir in westernWashington. The norms were tested using soil test and stand basal area growth response data from 20 thinned and 30 unthinned N fertilizer test sites in coastal Washington and Oregon. Response to urea fertilizer in thinned stands averaged 34% and 43% for 224 and 448 kg N.ha-1, respectively, when N was identified as the most limiting nutrient. When N was not the most limiting nutrient, N response averaged 8% and 10% for 224 and 448 kg N.ha-1, respectively. Results were similar in unthinned stands and thinned stands, although response to fertilizer appeared to be slightly less in unthinned stands when N was the most limiting nutrient. DRIS correctly classified 25 of the 33 sites (76%) where N fertilizer increased growth by more than 15%. More importantly, 13 of the 17 (76%) sites that responded by less than 15% were correctly identified by DRIS. The results clearly indicate that N fertilizer response is dependent on the interactions (balance) between soil nutrients at a given site. Future soil diagnostic work needs to focus on techniques, like DRIS, that provide an assessment of these interactions.

OSU Link
Non-OSU Link

124. Sonne, E., E. Turnblom, D. Briggs and G. Becker. 2004. Log and lumber grades and value from a Douglas-fir stand 20 years after thinning and biosolids fertilization. Western-Journal-of-Applied-Forestry 19(1): 34-41.

Keywords: fertilization
thinning
economics
yield
wood quality

Abstract: Three replications of four treatments: biosolids fertilizer application, thinning, thinning plus biosolids fertilizer application, and untreated control were established in 1977 in a dense, low site, 55-year-old Douglas-fir (Pseudotsuga menziesii) stand in western Washington, USA. In 1998, 12 trees from each treatment were harvested, bucked into logs, and sawn into visually graded lumber. Taking into account effects of treatments on stand yield and log grades, biosolid fertilizer application only, thinning only, and thinning combined with biosolids increased log value/ac by $1142 (19%), $3642 (62%), and $9969 (155%), respectively, over the untreated control. When treatment effects were viewed in terms of changes in lumber yield and quality, per acre gains over the control were $2107 (26%), $5683 (70%), and $10 708 (132%), respectively. Willingness to pay analysis indicates that if the landowner intends to manage the stand to a rotation of approximately 75 years, each of the treatments, and especially the combination of thinning and applying biosolids, appears to be financially attractive at both 5 and 9% interest rates. However, if the rotation had been set at 55 years, only the thinning/biosolids combination at 5% interest rate would entice management to delay immediate harvest.

OSU Link
Non-OSU Link

125. Stegemoeller, K.A. and H.N. Chappell. 1990. Growth response of unthinned and thinned Douglas-fir stands to single and multiple applications of nitrogen. Canadian-Journal-of-Forest-Research 20(3): 343-349.

Keywords: fertilization
thinning
growth

Abstract: Basal area and volume growth response of unthinned and thinned Douglas fir (Pseudotsuga menziesii) stands to single and multiple applications of N fertilizer (as urea) were estimated for eight 2-yr periods in second-growth stands in Washington and Oregon. Response estimates, as differences between growth rates on fertilized and control plots after adjusting for initial volume (or basal area), and trends, were analysed on a regional scale. Average responses to the initial fertilization and to both the second and third fertilizer applications, 8 and 12 yr later, were statistically significant ($P < 0.05$). In thinned stands, average duration of response to the initial treatment was approximately 8 yr; unthinned stands continued to show significant volume growth response through 14 yr although basal area growth response decreased to nonsignificant levels between years 10 and 12. In both cases, the response to

refertilization, while significant, was smaller than the response to the initial fertilization. N applied after the 8th yr and a refertilization after the 12th, on one initially untreated plot at each site, also produced significant average growth responses.

OSU Link
Non-OSU Link

126. Stegemoeller, K.A. and H.N. Chappell. 1991. Effects of fertilization and thinning on 8-year growth responses of second-growth Douglas fir stands. Canadian-Journal-of-Forest-Research 21(4): 516-521.

Keywords: fertilization
thinning
growth

Abstract: An evaluation is presented of a regional research project on basal area and volume increment responses to fertilizer (N) and fertilizer with thinning treatments of Pseudotsuga menziesii in W. Washington and Oregon for four 2-year measurement periods. Fertilization generally increased both basal area and volume growth for at least 8 years. Thinning tended to have an even greater effect than fertilization on basal area and volume growth on an individual-tree basis. Overall, however, the removal of growing stock by thinning caused volume growth to be less than that of the control. The magnitude and duration of this negative response was dependent on the level of thinning and on site quality. A significant positive interaction between fertilization and thinning exists. The combined treatment resulted in the greatest absolute basal area and volume increments, and the response became greater than that to fertilizer alone in the 3rd and 4th years, and remained so for at least 8 years.

OSU Link
Non-OSU Link

127. Strader, R.H. and D. Binkley. 1989. Mineralization and immobilization of soil nitrogen in two Douglas-fir stands 15 and 22 years after nitrogen fertilization. Canadian-Journal-of-Forest-Research 19(6): 798-801.

Keywords: fertilization
growth
soil properties

Abstract: Additions of 15N-labelled NH4Cl were used to examine the role of microbial immobilization in long-term growth response of Douglas fir (Pseudotsuga menziesii) plantations to N fertilizer treatment. Soil samples were collected in summer 1986 from fertilized (448 or 470 kg/ha N) and nonfertilized plots at previously established N fertilization experiments near Shawnigan Lake, British Columbia, and the Wind River Experimental Forest near Carson, Washington. Douglas fir on these sites were reported to still be responding to N fertilization after 12 and 18 years. Less than 2% of the added 15N was recovered as mineral N after a 14-day laboratory incubation of soil samples from the fertilized and nonfertilized plots. This indicates that gross mineralization could be >50x greater than net mineralization in these infertile soils if the remaining 98% of the added 15N were all biologically immobilized. Net mineralization was significantly greater (p <less or =>0.10) in soils from the fertilized plots than in those from the nonfertilized plots at the Wind River site. Although the current differences in N availability did

not appear to be related to differences in microbial immobilization, such large rates of immobilization require further investigation as a factor in long-term response to fertilization.

OSU Link
Non-OSU Link

128. Strand, R.F. and D.S. DeBell. 1981. Growth response to fertilization in relation to stocking levels of Douglas-fir. In Proceedings: Forest Fertilization
Conference, University of Washington, Seattle, Washington, USA. Eds. S.P. Gessel, R.M. Kenady and W.A. Atkinson.pp. 102-106.

Keywords: planting operations
fertilization
thinning
growth

Abstract: Growing stock levels affect the response of Douglas-fir stands to applications of nitrogen fertilizer. Response is maximum at intermediate stocking levels, and is less at higher or lower levels of stand density. Nitrogen fertilization accelerates growth and therefore increases the rate of buildup of stand density. Thinnings will be required to reduce stocking to appropriate levels if good responses to repeated nitrogen applications throughout a rotation are to be obtained.

OSU Link
Non-OSU Link

129. Tarrant, R.F., B.T. Bormann, D.S. DeBell and W.A. Atkinson. 1983. Managing red alder in the Douglas-fir region: some possibilities. Journal-of-Forestry 81(12): 787-792.

Keywords: planting operations
fertilization
yield
economics

Abstract: An economic comparison of 3 systems for growing Alnus rubra (rotations of 13,20 and 28 yr) in the Pacific Northwest USA, with or without alternating rotations (45 yr) of Douglas fir, and 2 continuous systems for growing Douglas fir (45-yr rotations with or without treatment with N fertilizer). Anticipated stand yield, and costs of site preparation, planting, fertilization etc. were used to estimate m.a.i. (vol.), present net worth and internal rate of return. The 2 most profitable systems were Douglas fir, thinned and treated with fertilizer twice in 45 yr (present net worth $623/acre) and red alder grown to sawlog size (28 yr) alternating with Douglas fir thinned twice in 45 yr (present net worth $578/acre). The least profitable system was red alder grown continuously in 13 yr rotations (present net worth -$251/acre). Alternate cropping of red alder and Douglas fir or continuous red alder production would be as profitable as growing Douglas fir alone if there were increases in real interest rate, alder stumpage price, or the cost of N fertilizer, or alder sawlog rotation length decreased.

OSU Link
Non-OSU Link

130. Tesch, S.D., G.M. Filip, S.A. Fitzgerald and D.D. Marshall. 1994. Silvicultural treatments for enhancing tree value, vigor, and growth in 70- to 120-year-old stands dominated by noble fir on the Warm Springs Indian Reservation: a synthesis of the literature. ForestResearch Laboratory, College of Forestry, Oregon State University. iii + 21 p.

Keywords: fertilization
thinning
pruning
tree/stand protection
growth
yield
tree/stand health

Abstract: The Warm Springs Indian Reservation, Oregon, apparently contains some 30 000 acres of naturally regenerated, largely unmanaged stands of 70- to 120-year-old mixed conifer forest dominated by noble fir (Abies procera), with Douglas-fir [Pseudotsuga menziesii], and some Pacific silver fir [Abies amabilis] and western hemlock [Tsuga heterophylla]. The synthesis focuses on growth and yield, thinning, pruning, fertilizer treatment, disease, minimizing stand damage during thinning, and insect pests.

Non-OSU Link

131. Thies, W.G. and E.E. Nelson. 1988. Bulldozing stumps and nitrogen fertilization affect growth of Douglas-fir seedlings. Canadian-Journal-of-Forest-Research 18(6): 803-806.

Keywords: site preparation
mechanical preparation
fertilization
growth

Abstract: Eight treatments involving stump removal (either all stumps removed or the plot left undisturbed) and broadcast application of ammonium nitrate (N at 0, 336, 672 or 1345 kg/ha) were applied to 0.04-ha circular plots in a clear felling on the Olympic Peninsula, Washington. Pseudotsuga menziesii seedlings were planted several months after treatment; d.b.h. and height were recorded 5 and 8 yr after planting. Results showed that either bulldozing stumps or application of nitrogen increased seedling growth. After 8 yr, bulldozing had increased seedling height and d.b.h. by 23 and 43%, respectively; increases caused by nitrogen fertilizer were 13 and 17%, respectively.

OSU Link
Non-OSU Link

132. Thies, W.G., E.E. Nelson and D. Zabowski. 1994. Removal of stumps from a Phellinus weirii infested site and fertilization affect mortality and growth of planted Douglas-fir. Canadian-Journal-of-Forest-Research 24(2): 234-239.

Keywords: site preparation
mechanical preparation

fertilization
tree/stand protection
tree/stand health
growth
soil properties

Abstract: A field study was established in a 4.9 ha clearcut on the west slope of the Cascade Range (44 degrees 21'N, 122 degrees 39'W), Oregon, to evaluate the effects of stump removal (of both infested and non-infested stumps) and fertilizing with ammonium nitrate on the incidence of laminated root rot (caused by Phellinus weirii) in Douglas fir (Pseudotsuga menziesii) seedlings. A 2x4 set of factorial treatments of stump removal in combination with nitrogen fertilizing was applied in August 1980 to 0.04-ha circular plots within the clearcut. Treatments included stump removal (either all stumps removed or the plot left undisturbed) and broadcast application of ammonium nitrate (0, 336, 672, or 1345 kg N/ha). Diameter at breast height and height of Douglas fir, planted as 2+1 bare root seedlings 4 months after treatment (in January 1981), were recorded 5 and 9 seasons after outplanting. Soil bulk density in the upper 20 cm was measured with a single-probe neutron densimeter. Stump removal reduced the number of seedlings killed by laminated root rot but had no significant effect on seedling growth. Stump removal increased soil bulk density only 7% as measured 9.7 years after treatment. Fertilizer increased the growth in diameter at breast height, and height growth of the seedlings but had no effect on mortality. There were no significant interactions between fertilizing and stumping treatments. Increased total soil N could still be detected on fertilized, nonstumped plots 9.7 years after treatment.

OSU Link
Non-OSU Link

133. Thies, W.G. and R.N. Sturrock. 1995. Laminated root rot in Western North America. Pacific Northwest Research Station, USDA Forest Service General Technical Report GTR-PNW-349. iv + 32 pp. p.

Keywords: planting operations
site preparation
mechanical preparation
fertilization
thinning
tree/stand protection
tree/stand health

Abstract: Laminated root rot, caused by Phellinus weirii, is a serious root disease affecting Douglas fir (Pseudotsuga menziesii) and other commercially important species of conifers in northwestern North America. This report gives an overview of the disease as it occurs in the Pacific Northwest in Canada and the USA. Information on recognizing crown symptoms and signs of the disease is presented. The disease cycle of laminated root rot, from initiation to intensification and distribution within infected stands, is described. Finally, disease management strategies during stand development and at stand regeneration are discussed. Features on the nomenclature of the fungus and on its management by silvicultural and mechanical approaches also are included.

OSU Link
Non-OSU Link

134. Thomson, A.J. and H.J. Barclay. 1984. Effects of thinning and urea fertilization on the distribution of area increment along the boles of Douglas-fir at Shawnigan Lake, British Columbia. Canadian-Journal-of-Forest-Research 14(6): 879-884.

Keywords: fertilization
thinning
tree morphology
growth

Abstract: Assessments were made using radial growth measurements made 6 and 9 yr after treatment. Within treatments, av. area increment per tree was linearly related to d.b.h. and this relation was used to evaluate the effects of treatment on growth rate. Fertilizing had the greatest effect on av. area increment, and for a particular fertilization regime, thinning increased the response. Thinning modified the distribution of growth over the bole of all trees and increased butt flare, especially in smaller trees. The effect declined from the 4- to 6-yr measurement period to the 7- to 9-yr measurement period. Fertilizing had no consistent effect on growth distribution. The regression methods used in this study provided a more sensitive measure of form changes than previous methods, were independent of size distribution, and facilitated extrapolations and evaluation of temporal trends.

OSU Link
Non-OSU Link

135. Thomson, A.J., K.D. Tudor, V.J. Korelus and D.R. Ralph. 1988. Detecting the response of Douglas-fir to nitrogen fertilization by regression of periodic annual basal area increment against basal area. Canadian-Journal-of-Forest-Research 18(10): 1343-1346.

Keywords: fertilization
growth

Abstract: Douglas-fir (Pseudotsuga menziesii) b.a. response to urea application at 112 and 224 kg N/ha was studied on a medium site on Vancouver Island, British Columbia. Regression of tree periodic annual b.a. increment against b.a. was used to estimate within-plot growth rates. Higher growth rates were observed in the plots treated with fertilizer. The slope coefficients of the regressions were used to investigate spatial and temporal variation in growth rates.

OSU Link
Non-OSU Link

136. Trofymow, J.A., H.J. Barclay and K.M. McCullough. 1991. Annual rates and elemental concentrations of litter fall in thinned and fertilized Douglas-fir. Canadian-Journal-of-Forest-Research 21(11): 1601-1615.

Keywords: fertilization
thinning
soil properties

Abstract: Overstorey litterfall (primarily needles) was collected for 15 years (1972-86) within control and treated plots in a Douglas fir (Pseudotsuga menziesii) stand near Shawnigan Lake, British Columbia. Treated plots were thinned or fertilized, or both. Thinned plots had two-thirds of their basal area removed; fertilized plots were treated with 448 kg N/ha of either urea or ammonium nitrate, and the fertilized plots were refertilized at the same rate 9 years later. The annual rate of litterfall in control plots averaged 1890 kg/ha. In control plots, significant yearly variations were observed in litterfall mass and concentrations of K, Mg, and Ca but not N or P. Thinning decreased rates of litterfall by 80%, but rates returned to control-plot levels after 13-15 years in unfertilized plots and after 8-10 years in fertilized plots. Fertilizer treatment without thinning depressed litterfall in the year of treatment but increased the rate by 20-80% in subsequent years. Litterfall N concentrations increased by 40-80% the year of fertilizer treatment and then began decreasing 3-6 years later. Nitrogen fertilization reduced litterfall P, K and Mg concentrations for 8, 4 and 1 year(s), respectively, following fertilizer treatment. The effects were greater in ammonium nitrate plots than in urea plots. Rates of litterfall correlated poorly with stand density but well with basal area and stemwood increment. Correlations with the latter two variables varied with time and treatment.

OSU Link
Non-OSU Link

137. Turner, J. 1982. The mass flow component of nutrient supply in three western Washington forest types. Acta Oecologica Oecologia Plantarum 3(4): 323-329.

Keywords: fertilization
soil properties
growth
tree physiology

Abstract: [See FA 37, 7318; 38, 5185; 39, 1857; 41, 3566; 44, 4913] The mass flow component of nutrient uptake, defined as the product of bulk soil sol. concn. and water uptake was calculated for a series of forest stands from previously published data. Stands were of Douglas fir of varying ages and nutrient status (both undisturbed and fertilized), red alder (Alnus rubra), Pacific silver fir (Abies amabilis) and beech (Fagus sylvatica). Uptake of N, P, K, and Mg increased, and Ca uptake remained stable as stands matured; the proportion of nutrient uptake fulfilled by mass flow tended to increase with stand age. Fertilizer application gave various results related to changes in soil sol. nutrient concn. and tree growth. The stands of red alder and silver fir showed variable patterns between nutrients and these are discussed in relation to soil nutrients, productivity and previously unpublished data.

OSU Link
Non-OSU Link

138. Turner, J., D.W. Johnson and M.J. Lambert. 1980. Sulphur cycling in a Douglas-fir forest and its modification by nitrogen application. Acta Oecologica Oecologia Plantarum 1(1): 27-35.

Keywords: fertilization
soil properties

Abstract: [See FA 39, 1857] In a study of a 42-yr-old nitrogen-deficient stand in Washington State, subject to acid rain and elevated inputs of S, excess S was found to be stored and cycled as SO4. A nitrogen (urea) fertilizer experiment reported previously resulted in the incorporation of foliar SO4 into organic S and a reduction in concn. of litterfall SO4. Nitrogen stress induced in the same experiment by addition of carbohydrate (sucrose and sawdust) to the forest floor resulted in greater return of SO4 via litterfall.

OSU Link
Non-OSU Link

139. Turner, J., M.J. Lambert and S.P. Gessel. 1988. Nitrogen requirements in young Douglas-fir of the Pacific Northwest. Fertilizer-Research 15(2): 173-179.

Keywords: fertilization
growth
tree physiology

Abstract: A series of fourteen Pacific Northwest Douglas-fir installations, ranging in age from 6 to 26 years were analysed with respect to site factors, foliage nutrients, and growth response to applied fertilizer. Unfertilized basal area increment ranged from 1.2 to 3.1 msuperscript 2 ha-1yr-1 with no apparent relationship with soil, stand age or site index. Basal area increment was correlated with foliage N and a critical level of N was calculated as 1.7%. Applications of 220 kg N ha-1 as urea increased growth between 0 and 95% of the unfertilized basal area growth, with an average of 24.9%. Response could be predicted from foliage N and unfertilized basal area increment. When the same relationships were applied to previously older stand data, results were more variable as elements such as B and S showed evidence of being limiting.

OSU Link
Non-OSU Link

140. Velazquez-Martinez, A. and D.A. Perry. 1997. Factors influencing the availability of nitrogen in thinned and unthinned Douglas-fir stands in the central Oregon Cascades. Forest-Ecology-and-Management 93(3): 195-203.

Keywords: fertilization
thinning
soil properties

Abstract: Soil N mineralized during 7-day anaerobic incubation at 40 degrees C (available N) was compared at 2 soil depths and correlated with soil and site factors in Douglas fir [Pseudotsuga menziesii] stands with different combinations of thinning and multinutrient fertilizing. Available N expressed either on an area basis (kg ha-1) or on a concentration basis (mg kg-1) at the 2 depths did not vary significantly by stocking density, treatment, or density-treatment interaction. There was a significant difference between the soil depths, averaging 39 mg kg-1 at 0-20 cm depth, and 20 mg kg-1 at 20-40 cm depth. Available N was positively correlated with total soil N, exchangeable Ca, and adjusted aspect (the former 2 factors accounting for 46% of the total variation), and negatively with rock content and slope steepness. Stand density had no effect.

OSU Link
Non-OSU Link

141. Velazquez-Martinez, A., D.A. Perry and T.E. Bell. 1992. Response of aboveground biomass increment, growth efficiency, and foliar nutrients to thinning, fertilization, and pruning in young Douglas-fir plantations in the central Oregon Cascades. Canadian-Journal-of-Forest-Research 22(9): 1278-1289.

Keywords: fertilization
thinning
pruning
growth
carbon allocation
tree physiology
tree morphology

Abstract: The effect of thinning and silvicultural practices (multinutrient fertilization and/or pruning) on total aboveground biomass increment and growth efficiency was studied over three consecutive 2-year periods (1981-1987) in young Douglas fir (Pseudotsuga menziesii) plantations in the central Oregon Cascades. Plantations were 21-27 yr old in 1987. Plots were heavily thinned (leaving 300 trees/ha), moderately thinned (leaving 604 trees/ha) or left unthinned (leaving 3459 trees/ha) in 1981. Fertilizer (N, P, K, Ca, S and Fe) was applied with slow-release tabs. Net above-ground biomass annual increment over the 6-year period averaged 14.5, 7.8, and 5.5 t/ha for the high-, medium-, and low-density plots, respectively. Growth efficiency, after dropping sharply between leaf area indexes (LAI) of 1 and 6 msuperscript 2/msuperscript 2, remained relatively constant up to the highest measured LAI of 17. Consequently, above-ground biomass increment continued to increase at LAIs well above that at which the Beer-Lambert law predicts maximum light should be absorbed. Foliage analyses indicated that thinning improved N, K and Mg nutrition and increased the translocation of K from 1-yr-old foliage to support new growth. However, fertilizer application increased foliar N and P contents only when coupled with pruning, suggesting that trees favour total leaf area over individual needle nutrition. Indications of K and Mg limitations in this study are supported by other recent studies of Douglas fir.

OSU Link
Non-OSU Link

142. Vogt, K.A., D.J. Vogt, E.E. Moore, W. Littke, C.C. Grier and L. Leney. 1985. Estimating Douglas-fir fine root biomass and production from living bark and starch. Canadian-Journal-of-Forest-Research 15(1): 177-179.

Keywords: fertilization
tree morphology
tree physiology

Abstract: A potential indirect technique for determining fine root biomass and production is reported. Data from 4 permanent Douglas fir plots in Washington State given different fertilizer treatments showed a direct correlation between the starch content of a 1-cm wide band of living bark at b.h. per hectare and fine root biomass per hectare (rsuperscript 2 = 0.85). Starch content was determined in

bark samples from 5 trees in each plot and estimates of the volume of 1-cm wide bands of bark at b.h. were made from measurements of d.b.h. and total bark thickness of every tree in each plot. Fine root biomass was determined in soil cores obtained with a post hole digger (inner diam. 15.3 cm); traditional small core methods could not be used because of the high gravel and rock content of the soil.

OSU Link
Non-OSU Link

143. Walker, R.B., S.P. Gessel and R.E. Miller. 1994. Greenhouse and laboratory evaluation of two soils derived from volcanic ash. Northwest-Science 68(4): 250-258.

Keywords: fertilization
growth
tree/stand health
carbon allocation
tree morphology
tree physiology

Abstract: This study assessed the mineral nutrient status of two soils derived from volcanic ash in SW Oregon. The study was initiated because conifers in some of the field plots on such soils had failed to give an expected yield response to the application of nitrogen fertilizer. Soil pot tests were carried out using both Romaine lettuce (Lactuca sativa) and Douglas fir (Pseudotsuga menziesii) seedlings, with a wide range of fertilizer treatments. Heavy phosphorus fertilization was necessary for satisfactory growth of lettuce, which also showed a 26% response to sulfur addition. With Douglas fir, pot tests showed no response to nitrogen alone, but gave a statistically significant response to phosphorus fertilization together with nitrogen (seedlings were non-mycorrhizal), and some suppression of yield with sulfur additions. There was a favourable effect of sulfur fertilization on foliar colour, and a chlorosis in younger foliage probably attributable to iron deficiency. Most of the tissue analyses showed low concentrations of magnesium (<0.05%), and also of calcium (<less or =>0.08%), iron (<70 mg/kg), boron (mostly 20 mg/kg) and copper (<less or =>2.6 mg/kg) in the younger foliage. Thus there is an implication from the field trials, and evidence from the greenhouse and laboratory study, that elements besides nitrogen need to be added to provide proper nutrition on these volcanic ash soils. The information can aid in guiding further fertilizer trials in forests on volcanic ash derived soil in SW Oregon and elsewhere.

OSU Link
Non-OSU Link

144. Weetman, G.F., C.E. Prescott, F.L. Kohlberger and R.M. Rournier. 1997. Ten-year growth response of coastal Douglas-fir on Vancouver Island to N and S fertilization in an optimum nutrition trial. Canadian-Journal-of-Forest-Research 27(9): 1478-1482.

Keywords: fertilization
growth
yield
tree physiology

Abstract: A 27-year-old stand of coastal Douglas fir (Pseudotsuga menziesii) on Vancouver Island, British Columbia, was fertilized four times (1981, 1983, 1986 and 1988) with N as urea at six rates from 0 to 250 kg N/ha, with and without S coating (0-50 kg/ha). Current-year foliage was collected annually during 1981-85 and in 1990. Foliar N levels declined in the control plots over the 10-year period, but remained elevated in the fertilized plots. The increase in foliar N concentrations was commensurate with the amount of N added. Stand basal area response increased with increasing rates of N addition. The greatest response in relative basal area net increment was 4.52 msuperscript 2/ha (40%) in plots that received a total of 1000 kg N/ha during the 10 years. Over a 60-year rotation, about 62 msuperscript 3 of extra wood would be produced under this regime. There was no additional response to S added in conjunction with N, so the N + S plots received only a single application of fertilizer. Mortality was confined to smaller suppressed stems, mostly of species other than Douglas fir. Foliar N concentrations and basal area increment declined steadily following cessation of fertilizer application in these plots, but remained greater than those in control plots for the 10-year measurement period. The results suggest that sustained increases in growth response of Douglas fir can be achieved through repeated additions of N that maintain elevated concentrations of N in foliage.

OSU Link
Non-OSU Link

145. White, D.E. and M. Newton. 1990. Herbaceous weed control in young conifer plantations with formulations of nitrogen and simazine. Canadian-Journal-of-Forest-Research 20(11): 1685-1689.

Keywords: release treatments
chemical release
fertilization
stand conditions
tree/stand health
growth

Abstract: Weed control and second year survival and growth of newly planted 2+0 Douglas fir (Pseudotsuga menziesii) and 2+0 noble fir (Abies procera) seedlings were measured at 3 sites in Oregon after application of herbicide and fertilizer in a replicated complete factorial experiment with 4 levels of simazine (0, 2.2, 4.4, 8.8 kg/ha), 3 levels of N (0, 110, 220 kg/ha), 2 types of N (urea prill; urea + trimamino-s-triazine (TST) prill) and 2 kinds of formulations (co-granular prill of simazine + nitrogen; nitrogen prill followed by liquid simazine). For the first growing season, total weed and grass control increased with increasing simazine rates. Total weed control was better when urea + TST, rather than urea alone, was applied in conjunction with simazine. Formulation and nitrogen rate were not significant. After plot treatment with 1.1 kg liquid hexazinone/ha at the beginning of the second growing season, Douglas fir survival decreased as the rate of urea alone increased; survival decreased with little or no weed control and remained constant or increased with good weed control as the rate of urea + TST increased. Noble fir height and diameter, and Douglas fir diameter, decreased with poor weed control, but increased at least to the levels of untreated seedlings with good weed control. Noble fir diameter responded positively to added nitrogen. Although simazine may be toxic to first year conifers, this study suggests that more complete weed control in conjunction with fertilization may benefit young conifer plantations.

OSU Link
Non-OSU Link

146. White, D.E., L. Witherspoon-Joos and M. Newton. 1990. Herbaceous weed control in conifer plantations with hexazinone and nitrogen formulations. New-Forests 4(2): 97-105.

Keywords: release treatments
chemical release
fertilization
stand conditions
growth
tree/stand health

Abstract: In order to determine if herbicide efficacy is affected by nitrogen fertilizer, and to examine the effects of treatments on growth and survival of newly-planted 2-year-old Douglas fir (Pseudotsuga menziesii) and 3-year-old noble fir (Abies procera), the influence of different nitrogen fertilizers applied in different combinations with hexazinone formulations were evaluated on three herbaceous weed communities in Oregon. Field studies comparing three application methods in conifer plantations showed greatest reduction in total weed cover with a co-granular formulation of hexazinone and the slow-release nitrogen fertilizer triamino-s-triazine (TST). Slightly less control was achieved with separate applications of liquid hexazinone and TST granules, and poorest control with granular urea followed by liquid hexazinone. Weed control increased with an increase in hexazinone rate. Statistical analysis of the effect on conifers showed that the highest hexazinone rate significantly increased survival of noble fir, stem diameter of both noble fir and Douglas fir, and that the highest nitrogen rate significantly reduced 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 co-granular formulation of hexazinone and TST granules was used.

OSU Link
Non-OSU Link

147. Wimberly, M.C. and B.B. Bare. 1996. Distance-dependent and distance-independent models of Douglas-fir and western hemlock basal area growth following silvicultural treatment. Forest-Ecology-and-Management 89(1/3): 1-11.

Keywords: fertilization
thinning
growth

Abstract: Distance-independent and distance-dependent individual-tree basal area growth equations for Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) growth following thinning and fertilizer treatments were developed using regression analysis. Data came from an even-aged, naturally regenerated, mixed species stand near Jordan River, SW Vancouver Island, Canada. Distance-independent models included only non-spatial competition and thinning indices, while distance-dependent models included both spatial and non-spatial indices. The distance-independent models with the highest adjusted multiple coefficient of determination (adjusted Rsuperscript 2) for both species included diameter at breast height, crown class, percent basal area removed in thinning, plot basal area greater than the subject tree and stand age as independent variables. The distance-dependent models with the highest adjusted Rsuperscript 2 included all of these variables in addition to a variant of the area potentially available index, which is based on the spatial tessellation of the point pattern of trees in the stand. Addition of this spatial index produced only a small (<.01) increase in

adjusted Rsuperscript 2 for models of both species. The relatively small amount of increase was due to three factors: thinning resulted in an even distribution of growing space among residual trees; tree size explained much of the variation in local competitive stress; and the competitive neighbourhood of individual trees was large relative to sample plot size. The results suggest that the additional effort and expense required to obtain spatially referenced stand data for developing empirical forest growth models in similar stands is not justified.

OSU Link
Non-OSU Link