Nursery Operations

1. Adams, W.T., S.N. Aitken, D.G. Joyce, G.T. Howe and J. Vargas-Hernandez. 2001. Evaluating efficacy of early testing for stem growth in coastal Douglas-fir. Silvae-Genetica 50(3/4): 167-175.

Keywords: genetic tree improvement
nursery operations
growth
genetic relationships

Abstract: In a test to evaluate the ability to predict stem growth of families in the field from nursery performance (i.e., early testing), 67 open-pollinated families and 66 full-sib families of coastal Douglas-fir (Pseudotsuga menziesii var. menziesii) were sown in two nursery conditions, each replicated as separate experiments: two bareroot nursery trials established in successive years in the same nursery, and two container-sown greenhouse trials sown in different greenhouses in the same year. First year heights in the seedling trials were compared to mean stem volumes of the same open-pollinated families in eight 15-year-old field progeny tests and the same full-sib families in eleven 12-year-old tests. Family mean nursery-field correlations (rxy) were similar for all four seedling trials for both open-pollinated (OP) and full-sib (FS) families, and generally ranged between 0.30 and 0.40. Although low, it is shown that nursery-field correlations of this magnitude can be quite useful in tree improvement programmes. For example, based on the data in this study, it is estimated that a single stage of family selection for first year seedling height would be about 50% as effective in improving 15-year volume as direct selection for this trait in field tests. Early testing, however, is probably of more practical significance as a tool for culling families prior to out-planting field tests in two-stage selection schemes. It is estimated that 25% of the OP families in this study could have been culled in an early test (first stage selection), with gain in 15-year volume after subsequent field testing and selection of the remaining families (second stage selection) being nearly the same as if all families had been field tested. Thus, early testing is an effective tool for reducing the size and cost of field progeny tests without sacrificing genetic gain.

2. Alvarez, I.F. and R.G. Linderman. 1983. Effects of ethylene and fungicide dips during cold storage on root regeneration and survival of western conifers and their mycorrhizal fungi. Canadian-Journal-of-Forest-Research 13(5): 962-971.

Keywords: nursery operations
tree/stand health
mycorrhizal response

Abstract: Survival and growth of Pseudotsuga menziesii, Pinus ponderosa and Abies concolor seedlings, and survival of mycorrhizal fungi on their roots were assessed after cold storage with or without 5 p.p.m. ethylene in combination with 4 root treatments: washed, dipped in Truban [etridiazole] or Benlate sol. or not treated. Ethylene treatment resulted in increased survival, apical bud burst, and new root formation in the greenhouse if roots had not been washed or dipped in fungicide. None of the gas storage or root treatments greatly affected seedling survival in the field. Root washing decreased

seedling vigour, especially in fir. None of the root treatments or gas storage conditions affected root fungal populations; bacterial and actinomycete populations appeared to be affected and the response varied according to host species. Pisolithus tinctorius, which formed mycorrhizae with 10-20% of the short roots of the seedlings, did not survive cold storage. Thelephora spp. and an ectendomycorrhizal fungus both survived cold storage and rapidly colonized roots newly formed on seedlings planted after cold storage.

OSU Link
Non-OSU Link

3. Alvarez, I.F. and J.M. Trappe. 1983b. Effects of application rate and cold soaking pretreatment of Pisolithus spores on effectiveness as nursery inoculum on western conifers. Canadian-Journal-of-Forest-Research 13(3): 533-537.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Ponderosa pine, Douglas fir, Shasta red (Abies magnifica var. shastensis), and white fir (Abies concolor) seedlings were inoculated in a bare root nursery with basidiospores of Pisolithus tinctorius. The spores were applied at 3 rates with or without cold/wet pretreatment of 7 or 21 days. Pretreatment did not affect spore efficiency as inoculum. Only ponderosa pine increased growth in response to inoculation. Inoculations in the greenhouse with a wider range of spore application rates revealed that a higher concn. of spores was needed to induce an increase in growth and mycorrhiza formation of Douglas fir than ponderosa pine. These levels were much higher than those used in nursery inoculations.

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4. Arnott, J.T. and D. Beddows. 1982. Influence of Styroblock container size on field performance of Douglas-fir, western hemlock, and Sitka spruce. Tree Planters' Notes 33(3): 31-34.

Keywords: nursery operations
growth
tree/stand health

Abstract: Pseudotsuga menziesii, Tsuga heterophylla and Picea sitchensis seeds were sown in April 1971 in BC/CFS Styroblocks sizes 2 and 8 with volumes of 40 and 125 cmsuperscript 3 respectively. The seedlings in the larger containers were kept in a heated greenhouse for 2-3 months to stimulate growth to fill the containers, before joining those in the smaller containers in an outdoor shadehouse nursery. Seedlings were planted out in British Columbia in March 1972. A second trial was started in April 1972 and seedlings planted out in April 1973. Survival and ht. growth were recorded for 5 growing seasons. The larger containers produced larger seedlings at planting. There were n.s.d. in survival of seedlings grown in the different sized containers for all 3 species. The seedlings grown in the larger containers were significantly taller after the first growing season in the field, a difference which persisted for the 5 seasons. Growing seedlings in the larger containers was more expensive and the seedlings took longer to plant than those grown in the smaller containers.

OSU Link
Non-OSU Link

5. Arnott, J.T. and F.T. Pendl. 1994. Field performance of several tree species and stock types planted in montane forests of coastal British Columbia. Canadian-Forest-Service, Pacific and Yukon Region Information Report BC-X-347. viii + 45 p.

Keywords: nursery operations
planting operations
growth
tree/stand health
wood quality

Abstract: Planting trials were established at sites within the Mountain Hemlock and montane Coastal Western Hemlock biogeoclimatic zones. Six test areas were chosen within each zone. Amabilis fir (Abies amabilis), noble fir (A. procera), yellow cedar (Chamaecyparis nootkatensis) and mountain hemlock (Tsuga mertensiana) were the species selected for planting in the Mountain Hemlock zone. In addition to Abies amabilis and A. procera, western white pine (Pinus monticola), western redcedar (Thuja plicata), Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) were planted in the Coastal Western Hemlock zone. Plug (PSB 211), plug transplant and bareroot stock types were used for the eight species across both zones. Seedlings were planted during the autumn (September/October) and spring (May) in each of two successive years: 1978-79 and 1979-80. Survival, growth and tree form 13 years after planting were used as indicators of the reliability (a combination of tree survival and form) and productivity of the planting treatment combinations. Noble fir and amabilis fir were the most reliable species in the Mountain Hemlock zone; i.e. these species have average survival rates higher than 80% and few form defects. Yellow cedar crowns were badly broken by snow, which reduced the reliability of this species in the early years of plantation establishment. The growth, survival and form of mountain hemlock ranked between that of the true firs and yellow cedar. Noble fir was by far the most productive species in the Mountain Hemlock zone. Within the Coastal Western Hemlock zone no single species demonstrated a superior combination of productivity or reliability. Douglas fir, western hemlock and western redcedar were good species in the lower elevations of the zone, whereas noble fir and amabilis fir were better species at the upper elevational limits of the zone. Western white pines should be avoided until rust-resistant seed sources are available. Little variation was found among the three planting stock options and even less between the two planting seasons. Plug transplant stock was more reliable than bareroot or plug stock; productivity ranked from greatest to least in the following order within both zones: plug transplant, bareroot and plug stock. This ranking among stock types may well change as different stock types are developed. However, the relative size and design differences among stock types, no matter when they become available, will always have an effect on the ultimate reliability and productivity of planted trees. Autumn planting gave significantly lower survival in the Coastal Western Hemlock zone only.

OSU Link
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6. Axelrood, P.E., M. Neumann, D. Trotter, R. Radley, G. Shrimpton and J. Dennis. 1995. Seedborne Fusarium on Douglas-fir: pathogenicity and seed stratification method to decrease Fusarium contamination. New-Forests 9(1): 35-51.

Keywords: nursery operations
tree/stand protection
tree/stand health
growth

Abstract: Twelve Douglas-fir (Pseudotsuga menziesii) seedlots from coastal British Columbia were assayed for seedborne Fusarium; all of the seedlots were contaminated. The percentage of non-stratified seeds from individual seedlots harbouring Fusarium ranged from 0.3 to 95.4. Sixty-seven percent of the seedlots had Fusarium on less than 2% of the seeds. Post-stratification seedborne Fusarium levels were significantly less for running water imbibition compared with standing water imbibition. However, seedling growth at a container nursery was not consistently different for stratified seed imbibed initially in standing or running water. Fusarium disease symptoms were not observed in the nursery environment. The species of Fusarium isolated from seed were F. acuminatum [Gibberella acuminata], F. avenaceum [G. avenacea], F. lateritium [G. baccata], F. moniliforme [G. fujikuroi], F. oxysporum, F. poae and F. sambucinum [G. pulicaris]. Twelve Fusarium isolates, comprising 6 species, were assessed for pathogenicity. Disease symptoms were observed after 4 weeks incubation and Fusarium isolates ranged in virulence from low to high. Fusarium oxysporum isolates were the most pathogenic.

OSU Link
Non-OSU Link

7. Axelrood, P.E. and R. Radley. 1991. Biological control of Fusarium on Douglas-fir seedlings. Bulletin-SROP 14(8): 85-87.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: A bacterial culture collection was established from the rhizosphere and rhizoplane of Douglas fir (Pseudotsuga menziesii) seedlings collected from nursery and forest locations in British Columbia, Canada. Of the 2000 strains screened, 350 inhibited growth of at least 1 conifer seedling root pathogen (Fusarium, Cylindrocarpon or Pythium) in in vitro antibiosis assays. A total of 96 strains were screened for Fusarium disease control in biological control assays. One strain that inhibited all 3 pathogens in vitro was able to significantly reduce the incidence of disease caused by Fusarium on P. menziesii seedlings. Another strain that tested negative in in vitro antibiosis assays also reduced the disease incidence by a similar amount. This paper was presented at the Second international workshop on plant growth-promoting rhizobacteria - progress and prospects, held in Interlaken, Switzerland, Oct. 14-19, 1990.

8. 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

9. Berch, S.M. and A.L. Roth. 1993. Ectomycorrhizae and growth of Douglas-fir seedlings preinoculated with Rhizopogon vinicolor and outplanted on eastern Vancouver Island. Canadian-Journal-of-Forest-Research 23(8): 1711-1715.

Keywords: nursery operations
mycorrhizal response
growth

Abstract: Ectomycorrhizal colonization of container-grown Douglas fir (Pseudotsuga menziesii) inoculated with Rhizopogon vinicolor was determined after cold storage and one growing season after outplanting (in March 1988) on a clear felled area on eastern Vancouver Island, British Columbia. Inoculated Douglas fir seedlings were taller than noninoculated controls when outplanted, but perhaps because of browse damage, no growth differences were found after one growing season in the field. R. vinicolor colonized all of the inoculated but none of the control seedlings examined after cold storage. Volunteer Thelephora terrestris colonized almost half of the control and 10% of the inoculated seedlings before outplanting. After one field season, inoculated and control seedlings were colonized by 15 ectomycorrhizal fungi each, only eight of which were found on both. R. vinicolor persisted on the roots of inoculated plants, but was also present in the field soil since the control seedlings also bore these mycorrhizas after one growing season. The relative abundance of T. terrestris decreased from the nursery to the field. The other common ectomycorrhizas in the field included Mycelium radicis atrovirens, Cenococcum geophilum and types resembling Tuber and Endogone.

OSU Link
Non-OSU Link

10. Birchler, T.M., R. Rose and D.L. Haase. 2001. Fall fertilization with N and K: effects on Douglas-fir seedling quality and performance. Western-Journal-of-Applied-Forestry 16(2): 71-79.

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

Abstract: Coastal Douglas fir (Pseudotsuga menziesii) 1+1 seedlings from coastal Oregon, USA, were applied with two fertilizers (NH4NO3+K2SO4 and (NH4)2SO4+KCl) at four rates (0, 80, 160, 320 kg N and K/ha) split over three application dates (September 19, October 13, November 1, 1996). Fertilizer type

did not affect total Kjeldahl nitrogen (TKN) levels on any of the sampling dates. By January 10, TKN concentrations had increased 16, 30 and 34%, and chloride concentrations had increased 57, 77 and 112% relative to the seedlings without fertilizer, for 80, 160 and 320 kg N+K/ha treatments, respectively. Nitrate levels increased briefly after the first application of NH4NO3+K2SO4. Potassium levels remained relatively unchanged. Levels of most other nutrients, as well as foliar dry weight, increased between September 16 and January 10, but these increases were generally unrelated to the fertilizer treatments. Root growth potential and cold hardiness did not differ among treatments. Seedlings that received 160 or 320 kg N/ha broke bud an average of 3 days earlier than the seedlings without fertilizer. Chlorophyll fluorescence (Fv/Fm) of seedlings with fertilizer was consistently higher than that of seedlings without fertilizer on November 13 and December 30. These treatment differences were not reflected in seedling outplanting performance after one growing season.

OSU Link
Non-OSU Link

11. Black, C.H. 1988. Interaction of phosphorus fertilizer form and soil medium on Douglas-fir seedling phosphorus content, growth and photosynthesis. Plant-and-Soil 106(2): 191-199.

Keywords: nursery operations
nursery fertilization
growth
tree physiology
photosynthesis

Abstract: Douglas-fir seedlings were grown in containers in peat-vermiculite or mineral soil each amended with different levels of concentrated superphosphate (CSP) or a granulated North Carolina phosphate rock (RP). Dilute acid-fluoride extractable phosphorus (DAP), seedling photosynthesis, weights, and tissue P concentrations were measured at 65 + 3 and 105 + 3 days.DAP was highly correlated with soluble fertilizer P (but not total P) added at the beginning of the experiment. Considerable soluble P was lost from peat-vermiculite but not from the mineral soil. Seedling total P content was proportional to the amount of soluble P per container at both harvests, but was greater for a given level of soluble P in the organic versus the mineral medium. Added soluble P increased foliar P concentrations, plant P content, and dry weight. Net carbon uptake was highly correlated with added levels of soluble P, foliar P concentrations, and with total P content. The internal efficiency of P from the RP source was less than P from CSP with respect to P content versus growth, net CO2 uptake, and net photosynthesis rates. At the end of the experiment, seedling P content plus DAP remaining in the media for the higher fertilizer rates accounted for 75% of the originally added soluble P in the mineral soils, but for only 15% in the organic media.

OSU Link
Non-OSU Link

12. Blake, J.I., R. Linderman and D. Lavender. 1988b. Seedling vigor of Douglas fir and western hemlock in relation to ethylene exposure levels and ethane production during cold storage. *In* Proceedings: 10th North American Forest Biology Workshop, 'Physiology and genetics of reforestation', University of British Columbia, Vancouver, British Columbia, July 10-22, 1988. *Eds.* J. Worrall, J. Loo-Dinkins and D.P. Lester. pp. 235-242.

Keywords: nursery operations
tree morphology
tree phenology
tree/stand health

Abstract: The effects were examined of ethylene treatment on Pseudotsuga menziesii and Tsuga heterophylla 2-yr-old bare root seedlings lifted in October or December (in a nursery in Washington) and stored for 2 and 7 days. Seedlings exposed to 0.5 p.p.m. ethylene at +1 degrees C for 7 days exhibited reduced bud and root activity. These effects were apparently reversed at 5.0 p.p.m. In a second experiment, reducing ethylene concentrations with KMnO4 during storage at +1 or +10 degrees C for 30 days did not affect foliage colour, but root and bud activity were generally enhanced. Ethylene concentrations in control bags ranged from 0.80 to 2.24 p.p.m. in October-lifted seedling bags and from 0.10 to 1.3 p.p.m. in December-lifted samples. The quantity of ethane in stored bags of P. menziesii seedlings was closely related to an increase in foliage discoloration. Little or no ethane was measured in T. heterophylla storage bags.

Non-OSU Link

13. Blake, J.I. and R.G. Linderman. 1992. A note on root development, bud activity, and survival of Douglas-fir, and survival of western hemlock and noble-fir seedlings, following exposure to ethylene during cold storage. Canadian-Journal-of-Forest-Research 22(8): 1195-1200.

Keywords: nursery operations
tree morphology
tree phenology
tree/stand health

Abstract: Three cold storage experiments were conducted with bare-root (2+0) Douglas fir (Pseudotsuga menziesii) seedlings from coastal Oregon and eastern Washington Cascade sources. The objectives were to determine the effects of ethylene at ambient and below-ambient (absorbed by KMnO4 pellets) concentrations, and at 0.5 and 5 p.p.m. ethylene, during short-term storage on subsequent root development and bud activity, and to relate these results to survival in the field at sites in Washington and Oregon, after prolonged cold storage. Root numbers and lengths were measured 28 days after a 7-day storage period after lifting seedlings on 27 September and 1 December. In the coastal source, root numbers and lengths in the 5 p.p.m. ethylene treatment were, respectively, 46 and 49% greater in September, and 22 and 13% greater in December, than the controls. No comparable treatment effects were found for the Cascade source. Neither the KMnO4 nor the 0.5 p.p.m. ethylene treatments affected root development in either seed source. For terminal buds in the controls, the number of days to 50% bud break was increased 2-8 days by a 30-day cold storage period compared with a 7-day period. For the coastal source, no increase in the time to 50% bud break was observed in the 5 p.p.m. ethylene treatment. Seedling survival was evaluated in the field for the same treatments following 4 months cold storage for the Douglas fir sources, coastal western hemlock (Tsuga heterophylla), and noble fir (Abies procera). Survival for the 5 p.p.m. ethylene treatment compared with the control was increased by 55% in the coastal Douglas fir source and by 13% in western hemlock. These results suggest that stimulated root development and bud activity may be partially responsible for the observed survival increase following cold storage at elevated ethylene levels.

OSU Link
Non-OSU Link

14. Bledsoe, C.S. and R.J. Zasoski. 1983. Effects of ammonium and nitrate on growth and nitrogen uptake by mycorrhizal Douglas-fir seedlings. *In* Tree root systems and their mycorrhizas. *Ed.* D. Atkinson. pp. 445-454.

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

Abstract: In a greenhouse pot study, 1-yr-old mycorrhizal (inoculated with Hebeloma crustuliniforme) and non-mycorrhizal Douglas fir seedlings were grown in sandy forest soil amended with 10% of clay minerals (bentonite and/or kaolinite) and ammonium or nitrate fertilizer. Ht. growth, root and shoot DM and accumulation of nitrogen and P were greater in mycorrhizal than non-mycorrhizal seedlings, especially in the nitrate treatment. Ammonium interacted with kaolinite to reduce survival which again was poorer in the absence of mycorrhiza.

OSU Link
Non-OSU Link

15. Campbell, S.J. and P.B. Hamm. 1989. Susceptibility of Pacific Northwest conifers to Phytophthora root rot. Tree Planters' Notes 40(1): 15-18.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: One-yr-old bare-rooted seedlings of 11 conifer species were inoculated with (a) Phytophthora cactorum, (b) P. cryptogea, (c) P. drechsleri, (d) P. megasperma or (e) P. pseudotsugae. Development of above-ground symptoms and root disease was followed for 10 wk. Isolates of (a), (b) and (e) caused the most overall mortality and isolates of (d) the least. Pinus contorta, P. ponderosa, P. monticola, Larix occidentalis, Libocedrus decurrens, Picea sitchensis and P. engelmannii showed tolerance to the root disease, Abies grandis and Pseudotsuga menziesii showed intermediate susceptibility and A. magnifica and Tsuga mertensiana were quite susceptible. Results are discussed in relation to management of conifer nurseries in the Pacific Northwest.

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Non-OSU Link

16. Castellano, M.A. and J.M. Trappe. 1985. Ectomycorrhizal formation and plantation performance of Douglas-fir nursery stock inoculated with Rhizopogon spores. Canadian-Journal-of-Forest-Research 15(4): 613-617.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Basidiospores (0, 106, 107 or 108) of 7 species of hypogeous, ectomycorrhizal fungi were applied to 1-msuperscript 2 plots sown with 4 conifer species (Pseudotsuga menziesii, Pinus lambertiana, Abies concolor and Tsuga heterophylla) in a bare-root nursery inOregon. Inoculation with either Rhizopogon vinicolor or R. colossus succeeded with 2 provenances of Douglas-fir only. For R. vinicolor, the high spore-application rate produced the most mycorrhizae on the greatest number of seedlings. For R. colossus, the high spore-application rate produced the most mycorrhizae on the greatest number of seedlings of one seed source, while the medium rate did better with the other. Stem height and root collar diameter of seedlings did not differ significantly between treatments and controls. Douglas-fir seedlings inoculated or not inoculated with spores of R. vinicolor were outplanted at 2 yr old in southwestern Oregon. After 2 yr, inoculated seedlings had significantly greater survival, stem height, root collar diameter, and biomass than noninoculated seedlings. Although new feeder roots of both noninoculated and inoculated seedlings were colonized by indigenous fungi, R. vinicolor persisted on the old root systems of inoculated seedings and colonized new feeder roots.

OSU Link
Non-OSU Link

17. Castellano, M.A. and J.M. Trappe. 1991. Pisolithus tinctorius fails to improve plantation performance of inoculated conifers in southwestern Oregon. New-Forests 5(4): 349-358.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Bare root seedlings of Douglas fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta), white fir (Abies concolor), and grand fir (Abies grandis) were inoculated with Pisolithus tinctorius and subjected to standard nursery and cold storage practices. At age 2 years, seedlings were assessed for mycorrhizal status, and were planted out on a variety of sites in SW Oregon. After 1, 2 and 3 growing seasons root collar diameter and current year's shoot growth were measured (or a lateral branch if browsing had damaged main shoot). Results showed that inoculated seedlings performed no better than those which had not been intentionally inoculated but which had formed mycorrhizae with indigenous, nursery fungi (e.g. Thelephora terrestris, and possibly Inocybe spp.). Climate, planting sites and nursery practices in the Pacific Northwest differ drastically from those in the southeastern United States, where P. tinctorius has increased plantation survival and growth. It is concluded that further research is necessary on P. tinctorius and nursery inoculation of tree seedlings in thePacific Northwest.

OSU Link
Non-OSU Link

18. Chanway, C.P. 1997. Inoculation of tree roots with plant growth promoting soil bacteria: an emerging technology for reforestation. Forest-Science 43(1): 99-112.

Keywords: nursery operations
tree/stand protection
growth
tree/stand health
mycorrhizal response

Abstract: Results from studies performed with beneficial asymbiotic tree root associated bacteria are reviewed in this article in relation to the possible uses of such microorganisms for artificial forest regeneration. The review includes sections on plant growth promoting bacteria for pine (Pinus spp.), spruce (Picea spp.), Douglas fir (Pseudotsuga menziesii) and hemlock (Tsuga heterophylla). Seedling root systems are colonized heavily by asymbiotic soil bacteria, many of which have the potential to influence plant growth significantly. A heterogeneous group of these microorganisms is well known for their ability to colonize roots and stimulate growth of agricultural plant species, sometimes doubling seedling biomass accumulation only a few weeks after inoculation, but more usually resulting in less spectacular biomass gains (e.g., 15%-30% greater than uninoculated controls within a growing season). Plant growth promoting soil bacteria may exert such effects through a variety of mechanisms, and include microorganisms that stimulate seedling emergence or infection by symbiotic fungi and bacteria. Other plant beneficial soil bacteria possess biological control activity or are capable of transforming plants genetically. Inoculation of tree seedlings with such bacterial before outplanting would be an inexpensive, environmentally benign, and easily applied nursery treatment, but comparatively little work has been performed with these microorganisms in forestry. Recent results with various tree species, however, indicate that seedling performance can be significantly enhanced through bacterial inoculation of root systems: pine and spruce biomass increased 32%-49% 1 yr after inoculation and outplanting at a reforestation site. In addition, infection by desired species of ectomycorrhizal fungi can also be enhanced by inoculation with certain strains of root colonizing bacteria.

OSU Link
Non-OSU Link

19. Chanway, C.P., R.A. Radley and F.B. Holl. 1991. Inoculation of conifer seed with plant growth promoting Bacillus strains causes increased seedling emergence and biomass. Soil-Biology-and-Biochemistry 23(6): 575-580.

Keywords: nursery operations
growth
tree morphology

Abstract: Seeds of lodgepole pine (Pinus contorta), Douglas fir (Pseudotsuga menziesii) and white spruce (Picea glauca) were collected from 3 sites in British Columbia. Inoculation with Bacillus strains L5 and L6 significantly increased the rate of seedling emergence of spruce but did not affect subsequent seedling growth. Pine root growth was promoted by strain L5 in sterilized, but not non-sterile, growth medium. Strain L6 promoted pine root growth in sterilized medium, but also caused significant increases in seedling emergence, shoot weight and height, root weight and surface area, and root collar diameter when tested in non-sterile peat-vermiculite medium. The positive effects due to a single inoculation of pine with strain L6 at sowing were not detectable after 12 weeks growth. However, root growth was stimulated after 16 weeks growth if seedlings were re-inoculated with strain L6 mid-way through the experiment. Shoot-growth promotion was also detected when 1-yr-old pine seedlings were planted in pots and inoculated with strain L6. Douglas fir seedlings grown from seed inoculated with strain L5 had

increased root collar diameters, whereas those inoculated with strain L6 exhibited increased root surface area.

OSU Link
Non-OSU Link

20. Coleman, M., J. Dunlap, D. Dutton and C. Bledsoe. 1987. Nursery and field evaluation of compost-grown conifer seedlings. Tree-Planters' Notes 38(2): 22-27.

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

Abstract: Seedlings of Douglas fir (Pseudotsuga menziesii), noble fir (Abies procera) and ponderosa pine (Pinus ponderosa) were raised in beds that had been treated with 0, 2, 4 or 6 inches of compost (fir/hemlock sawdust and municipal sewage sludge, 3:1) at a nursery in Carson, Washington. In autumn 1983, the 2+0 stock was lifted, stored until spring 1984 and then planted out on Mt. St. Helens, Washington (Douglas fir), near Estacada, Oregon (noble fir) or E. of the Cascade crest near Leavenworth, Washington (ponderosa pine). Data are given on the ht., biomass and concn. of N, P, Zn, Cu, Pb, Ni and Cd after 1 yr in the nursery beds and on the ht. and survival for 2 yr after planting. The responses of the seedlings to the compost, the immobilization of nutrients and the accumulation of heavy metals are discussed.

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Non-OSU Link

21. Coleman, M.D., C.S. Bledsoe and B.A. Smit. 1990. Root hydraulic conductivity and xylem sap levels of zeatin riboside and abscisic acid in ectomycorrhizal Douglas fir seedlings. New-Phytologist 115(2): 275-284.

Keywords: nursery operations
nursery fertilization
tree morphology
tree physiology
mycorrhizal response

Abstract: The hypothesis that root hydraulic conductivity (LP) of ectomycorrhizal root systems is greater than that of non-mycorrhizal systems, and different to that of vesicular-arbuscular (VA) mycorrhizas was tested in a greenhouse experiment, by measuring hydraulic qualities of roots while accounting for seedling size and P content. Plant growth substances (abscisic acid and zeatin riboside) expressed from roots during the experiments were also measured. Douglas fir (Pseudotsuga menziesii) seedlings inoculated with the ectomycorrhizal fungi Laccaria bicolor and Hebeloma crustuliniforme, and non-inoculated seedlings infected naturally with Thelephora were grown under 3 rates of P fertilization (1, 10 and 100 micro M P). After 9 months, seedling morphology, tissue P concn., LP and plant growth substance concn. in xylem sap were measured. Increased tissue P and decreased root/shoot ratio

correlated with increased LP in each mycorrhizal treatment; when adjusted for the effect of these 2 factors, LP of Laccaria and Hebeloma seedlings was still lower than that of Thelephora seedlings. In a subsequent experiment, LP of seedlings with Hebeloma and Rhizopogon vinicolor mycorrhizas was compared with that of non-mycorrhizal seedlings (grown at 100 mM P) and no differences were found among treatments. The lack of an ectomycorrhizal effect on LP is quite different from the enhancement of host LP by VA mycorrhizas. Zeatin riboside concentrations of Thelephora- and Hebeloma-infected seedlings were similar, yet higher than with Laccaria. There was no relationship between plant growth substances and LP in ectomycorrhizal Douglas fir, despite lower zeatin riboside concentrations for Laccaria-inoculated plants.

OSU Link
Non-OSU Link

22. Copes, D.L. and N.L. Mandel. 2000. Effects of IBA and NAA treatments on rooting Douglas-fir stem cuttings. New-Forests 20(3): 249-257.

Keywords: nursery operations
tree morphology
tree/stand health

Abstract: The effectiveness of 6 indole-3-butyric acid (IBA) and four 1-napthaleneacetic acid (NAA) concentrations, 4 combinations of IBA and NAA concentrations, and control were tested for their ability to enhance rooting frequency of Douglas-fir [Pseudotsuga menziesii] cuttings. Two IBA and one NAA treatments were also compared to the control for quality of root system. Between 1984 and 1998, six independent studies were conducted in mist or fog environments with the 14 clones. Auxin concentrations tested ranged from 0 to 123 mM IBA and 0 to 10 mM NAA. Auxin, clone and auxin by clone effects were significant in every study, although individual clone analyses showed only two clones to differ significantly for auxin. All auxin treatments except the 10 mM NAA treatment induced significantly greater rooting percentage than the control, but no single auxin, auxin concentration or combination of auxins was clearly superior in every study. The 10 mM NAA concentration was the only concentration tested that reduced rooting percentage to less than the control. Both NAA and IBA appeared to have broad ranges of root-enhancing activity. However, within the effective range of IBA evaluated, 24.6 or 49.3 mM produced the greatest rooting percentage in 4 of 5 studies testing IBA. NAA solutions with concentrations between 2.5 and 7.5 mM NAA generally resulted in similar rooting success. Rooting responses to increased IBA and NAA were both nonlinear; rooting decreased with both too little and too much auxin. Combinations of IBA and NAA in the same solution did not increase rooting percentage above what was achieved with one auxin. For root system quality, auxin treated cuttings in one study, had significantly better root systems than control, but there was no difference in the other study in which root quality was estimated.

OSU Link
Non-OSU Link

23. DeYoe, D.R., H.R. Holbo and K. Waddell. 1986. Seedling protection from heat stress between lifting and planting. Western-Journal-of-Applied-Forestry 1(4): 124-126.

Keywords: nursery operations

planting operations
tree/stand protection
tree/stand health

Abstract: Seven protective treatments were evaluated for preventing overheating of 2+0 Douglas fir seedlings in Kraft paper bags. Trials were conducted in May 1982 at Corvallis, Oregon on 3 clear days with max. air temp. of 78 degrees F and a hazy day with max. temp. 66 degrees . Seedlings were returned to cold storage (35 degrees) overnight. Seedling temp. differed significantly between treatments. Unprotected seedlings (paper bag only) in full sun reached 89 degrees after 7 h. Green canvas caused increased heating rates and higher temp. (104 degrees after 7 h). A white sheet and a crinkled foil wrap performed no better than a paper bag alone. Canvas painted off-white reduced max. temp. to 80 degrees . Heavy shading (2% of full sun) and Mylar with white surface towards the sun were the most effective materials for preventing overheating (max. temp. 59-60 degrees). Mylar with the silver surface facing the sun was less effective (max. temp. 71 degrees).

OSU Link
Non-OSU Link

24. Donald, D.G.M. and D.G. Simpson. 1985. Shallow conditioning and late fertilizer application effects on the quality of conifer nursery stock in British Columbia. B.C.-Ministry-of-Forests Research-Note 99. viii + 36 p.

Keywords: nursery operations
nursery fertilization
tree/stand protection
tree morphology
tree/stand health
growth

Abstract: Eight trials on 2+0 stock of Picea engelmannii, P. glauca, P. sitchensis, Pinus contorta and Pseudotsuga menziesii (var. glauca and var. menziesii) in 4 nurseries were conducted to compare the effects of shallow conditioning (undercutting and wrenching at 10 cm deep) with those of the standard conditioning regime (undercutting and wrenching at 20 cm) on nursery performance, storage and field performance. The application of a complete NPK fertilizer 50 days before lifting was also evaluated. Shallow conditioning and late fertilizer application improved the root growth capacity at lifting, but could not replace cold exposure for hardening Pseudotsuga menziesii. Shallow conditioning had little effect on survival after planting and reduced initial ht. increment of all species. Application of fertilizer just before lifting improved the early growth of the trees without adversely affecting survival. Planting seedlings some 5 cm deeper than they stood in the nursery improved establishment.

OSU Link
Non-OSU Link

25. Drew, A.P. 1983. Optimizing growth and development of 2-0 Douglas-fir seedlings by altering light intensity. Canadian-Journal-of-Forest-Research 13(3): 425-428.

Keywords: nursery operations

tree/stand protection
growth
tree morphology
carbon allocation

Abstract: Seedlings were grown outdoors in Michigan in pots under 71% of full light the first growing season and full light the second. Another group of seedlings was given full light continuously for 2 yr. At the end of the 1st year, seedlings given initial shade had grown larger in total wt. (root + shoot) than those grown under full light. With removal of shading, the larger plants began to allocate increased dry matter to root development relative to their shoots. By the end of 2 yr, shoot/root ratios for the 2 groups were no different, yet the plants shaded in their 1st year were significantly heavier (dry wt.) By proper use of shading during development, larger 2+0 planting stock with good root development may be produced. Such stock, grown without the use of costly fertilizer, may be better suited to regeneration of droughty sites in the Pacific Northwest USA than the usual 2+0 planting stock, nursery grown under full light.

OSU Link
Non-OSU Link

26. Driessche, R.v.-d. 1983. Growth, survival, and physiology of Douglas-fir seedlings following root wrenching and fertilization. Canadian-Journal-of-Forest-Research 13(2): 270-278.

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

Abstract: Seedlings at different nurseries on Vancouver Island were subjected to wrenching treatments during their 2nd year of growth using a fixed blade at 20-25 cm below the bed surface. In the first experiment, wrenching reduced water potential of trees on unirrigated loam soil by an av. of 300 kPa during Aug. and Sept. Wrenched trees lifted in Oct. and stored at 2 degrees C until May, showed 25% higher survival than unwrenched trees 1 yr after planting. Trees lifted in Dec. had uniformly high survival (98%) and showed no effect of wrenching. Wrenched trees from irrigated plots had lower shoot length relative growth rates (RGR) than unwrenched trees during the year after planting. In the second experiment, wrenching treatments were applied to seedlings, growing in a loamy sand, for different periods between 15 May and 11 Sept. as follows: (a) no wrenching, (b) early summer, (c) midsummer, (d) late summer and (e) all summer. Three fertilizer treatments (none, and 2 amounts of NPK) were applied to each wrenching treatment, and seedlings were lifted for storage at 2 degrees C in Oct. and Dec. Stored trees and freshly lifted trees were planted at 700 m alt. on 3 March. Wrenching increased root dry wt., particularly when additional fertilizer was applied, but had no measurable effect on cold hardiness or root growth capacity. Nevertheless, late summer wrenching increased survival 5 and 7% above control 1 and 2 yr after planting. Wrenching had little subsequent effect on new shoot growth of planted trees during the 2 yr after planting. However, late-summer wrenched trees showed significantly more new shoot growth than all-summer wrenched trees. More fertilizer reduced cold hardiness and survival of cold-stored trees, but increased root growth capcity. Cold hardiness (measured by electrical impedance) was correlated with survival of cold-stored trees after planting (rsuperscript 2 = 0.82). Root

growth capacity, averaged over all fertilizer treatments was closely correlated with survival of stored and freshly lifted trees (rsuperscript 2 = 0.93). Foliar nutrient concn. were reduced by wrenching, but fertilizing increased nutrient reserves within the seedling.

OSU Link
Non-OSU Link

27. Driessche, R.v.-d. 1984a. Response of Douglas fir seedlings to phosphorus fertilization and influence of temperature on this response. Plant-and-Soil 80(2): 155-169.

Keywords: nursery operations
nursery fertilization
growth
tree physiology
carbon allocation
tree morphology

Abstract: In pot experiments levels of P fertilizers equivalent to 300 kg/ha were adequate for maximum growth of Douglas fir (Pseudotsuga menziesii var. menziesii) seedlings over 14-18 weeks, and resulted in available soil P levels of 80 ppm after 15 weeks' growth. Maximum growth in pots was obtained with shoot P concentrations of 0.18%-0.20%, with higher values at lower temperatures, but the optimum concentration for one-year-old (1-0) nursery seedlings was 0.16% P. Growth of seedlings was greatly restricted at a soil temperature of 5 degrees C and an air temperature of 12 degrees C. At a soil temperature of 10 degrees C and an air temperature of 14 degrees C seedling P requirement was greater than at soil and air temperatures of 20 degrees C. Monoammonium phosphate was more effective than calcium superphosphate in stimulating growth in pots and nursery beds. Triple superphosphate was also effective in the nursery. Diammonium phosphate, potassium dihydrogen phosphate and phosphoric acid had no advantages as P sources in the nursery. Available P levels of 100-130 ppm, in the loamy sand and sandy loam nurseries studied, and needle P concentrations of 0.18%, when sampled in October, were associated with maximum growth of two-year-old (2-0) seedlings. P fertilization decreased the root/shoot ratio, but did not alter the allometric relationship of shoot to root. Improving the P status from a low level increased the root growth capacity in 2-0 seedlings and P fertilization of potted seedlings increased the dry weight/height ratio. Uptakes per seed bed ha of 236 kg N, 31 kg P, 81 kg K and 73 kg Ca by 2-0 seedlings were comparable with, or greater than, uptake rates of agricultural crops. Recoveries of 6-11% of P from fertilizer were recorded in the nursery.

OSU Link
Non-OSU Link

28. Driessche, R.v.-d. 1984b. Seedling spacing in the nursery in relation to growth, yield, and performance of stock. Forestry-Chronicle 60(6): 345-355.

Keywords: nursery operations
growth
tree morphology
carbon allocation
tree physiology

tree/stand health

Abstract: In 3 experiments at nurseries in coastal British Columbia Picea sitchensis, P. glauca, Pinus contorta var. latifolia, Thuja plicata and coastal and interior varieties of Pseudotsuga menziesii were sown in May 1979, 1980 or 1982 and grown at spacings ranging from 0.5 to 12 cm. A 1-cm increase in spacing increased seedling dry wt. by 0.5-1.5 g and root collar diam. by 0.2-0.25 mm up to a spacing of about 8-10 cm. Above this, response was less. Ht. of 2-yr-old seedlings was increased slightly or even decreased by wider spacing. Height : diameter ratios decreased sharply and shoot : root dry wt. decreased or remained unchanged with wider spacing. The number of needle primordia in 2-0 P. menziesii buds increased up to a spacing of 2 cm, and the number of 1st and 2nd order branches were also increased by wider spacing. Increases in root growth capacity were associated with wider spacing in T. plicata and Picea sitchensis. In a test of 3 types of precision seeders, none produced anything like accurate seed placement. Irregularity was increased by 10-20% non-viable seed and winter mortality. Increased spacing of 2-5 cm between seedlings was justified by the yield of acceptable seedlings only when the culling standard was increased to a root collar diam. of about 6 mm. Three yr after planting out the survival of P. glauca was increased 11% by wider spacing. After 2 yr P. sitchensis survival was increased 13% by wider spacing. Both species grown at wider spacing maintained a ht. and diam. advantage over those from close spacing.

OSU Link
Non-OSU Link

29. Driessche, R.v.-d. 1987. Importance of current photosynthate to new root growth in planted conifer seedlings. Canadian-Journal-of-Forest-Research 17(8): 776-782.

Keywords: nursery operations
tree physiology
photosynthesis
tree morphology

Abstract: Reports are given of 6 experiments. Two-yr-old seedlings of Douglas fir and Sitka spruce, labelled with 14CO2 in Oct. and kept outdoors, contained 14C in old roots but little in new roots when placed in a growth chamber in Jan. New roots were highly radioactive in seedlings labelled with 14CO2 after 12 days' growth in Jan., indicating that current photosynthate was the primary C source for new roots. These results agreed with an experiment in which the number and wt. of new roots on 1+1 Douglas fir transplants were directly related to light intensity. Net photosynthesis (Pn) of similar Douglas fir nursery stock after cold storage was inadequate to supply C for respiration and new root growth under 16-h photoperiods of 200 micro E/msuperscript 2 per s, although new root growth occurred. This suggested that reserves contributed to respiration. Douglas fir seedlings began transpiration immediately after planting in moist soil. Two-yr-old lodgepole pine seedlings grown outdoors over winter with root systems maintained at <more or =>10 degrees C produced more new roots in spring than seedlings grown outdoors without heated roots or in a greenhouse; no relations were observed between new root growth and Pn.

OSU Link
Non-OSU Link

30. Driessche, R.v.-d. 1988a. Nursery growth of conifer seedlings using fertilizers of different solubilities and application time, and their forest growth. Canadian-Journal-of-Forest-Research 18(2): 172-180.

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

Abstract: Beginning in May 1982, seedlings of Douglas fir and white spruce were grown for 2 yr in a bare-root nursery in southern British Columbia. Seedlings were treated with four types of commercial fertilizers (slow-release Osmocote, ammonium phosphate, ammonium sulphate and Hi-Sol, a soluble fertilizer with 20-20-20 NPK) at 2 different frequencies during both years to give total N applications of 0, 210 or 350 kg/ha. In addition, Douglas fir seedlings that had been grown for 2 yr without fertilizer were treated with the same amounts of fertilizer as a late season treatment during 1 Sep.-20 Oct. 1983. Ammonium fertilizers produced larger seedlings than Osmocote and Hi-Sol. Dry wt. increased with application rate, but frequency of application had only a small effect. Fertilizer increased the proportion of stem dry matter and decreased the proportion of needle and root dry matter. Dry wt. of 2+0 white spruce seedlings was correlated with soil pH, extractable NO3 and available P measured in Sep. of the first growing season. Douglas fir seedlings were planted out in Mar. 1984. Late-season fertilized seedlings had greater N and P tissue concn. than seedlings fertilized during the growing season. Survival and growth rate after planting were also both greater in late-season fertilized seedlings. Results suggested that fertilizer composition was more important than fertilizer solubility for nursery growth.

OSU Link
Non-OSU Link

31. 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

32. Driessche, R.v.-d. 1991a. Influence of container nursery regimes on drought resistance of seedlings following planting. I. Survival and growth. Canadian-Journal-of-Forest-Research 21(5): 555-565.

Keywords: nursery operations
tree/stand protection
growth
tree morphology
carbon allocation
tree/stand health

Abstract: In a 2 year study, Douglas fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta) and white spruce (Picea glauca) seedlings, grown in Styroblock containers in a container nursery from February to July 1988, were exposed to three temperatures and three levels of drought stress applied factorially during 18 July to 29 September 1988. Mean temperatures of 13, 16 and 20 degrees C were imposed in growth chambers, in a cooled plastic house, and in an ambient plastic house, respectively. Control, medium and severe levels of drought stress were imposed in a series of eight cycles, resulting in mean xylem pressure potentials of -0.32, -0.50 and -0.99 MPa, respectively. Seedlings were kept in the ambient plastic house until January 1989, when they were lifted and cold-stored until transplanting to covered 0.5-m deep sand beds, which provided hygric, mesic, and xeric conditions for testing all species and treatments. At the end of nursery growth, an increase in nursery temperature increased height and height : diameter ratio in all species and shoot:root dry weight ratio in Douglas fir and lodgepole pine. Increase in temperature also increased the number of seedlings with large well-formed buds in white spruce, but reduced the number in Douglas fir. Drought stress reduced height and dry weight in all species and bud length in lodgepole pine. After 9 weeks in sand beds, low nursery temperature increased survival (19% for lodgepole pine and white spruce grown in the xeric bed), except for Douglas fir grown in the xeric bed. Nursery drought stress also increased survival (16% for Douglas fir and lodgepole pine in the xeric bed), but had little effect on white spruce. Low temperature and drought stress treatments that increased survival also reduced height and dry weight of lodgepole pine and white spruce after one growing season in sand beds. Survival showed significant negative correlations with height, dry weight and height:diameter and shoot : root weight ratios. Low nursery temperature continued to affect growth 16 weeks after planting, increasing relative growth rate and allometric ratio (K) of Douglas fir and reducing K of white spruce.

OSU Link
Non-OSU Link

33. Driessche, R.v.-d. 1991b. Influence of container nursery regimes on drought resistance of seedlings following planting. II. Stomatal conductance, specific leaf area, and root growth capacity. Canadian-Journal-of-Forest-Research 21(5): 566-572.

Keywords: nursery operations

tree/stand protection
tree physiology
tree/stand health

Abstract: Seedlings of Douglas fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta) and white spruce (Picea glauca) were grown in a container nursery from February to July 1988 and then exposed to three temperatures and three levels of drought stress applied factorially during mid-July to October 1988. Seedlings were retained in a shelter house until January 1989, when they were cold-stored until early May. Measurements of stomatal conductance (gs), transpiration (E), and specific leaf area (SLA) were made at the end of the treatment period in September 1988 and again after growth the following year at the end of June. Root growth capacity (RGC) was tested in early May 1989. Results were considered in conjunction with performance of other samples of the same plants that had been planted in sand beds in April 1989, where irrigation was regulated to provide three levels of moisture stress. Low temperature (13 degrees C) generally reduced gs and E, which were adjusted for xylem pressure potential, and SLA, in all species by the time nursery treatment was completed at the end of September. No effect of nursery temperature treatment on gs or E could be detected when new needles were measured in June and July (after 9 to 12 weeks of growth), but SLA of lodgepole pine increased with nursery temperature treatment, andSLA of white spruce decreased with treatment. RGC was higher for the 13 degrees C treatment than for the 16 and 20 degrees C treatments. Survival of outplanted seedlings was mainly inversely related to nursery temperature. Low nursery temperature reduced gs, E, andSLA and increased RGC. SLA of planted lodgepole pine increased with level of nursery drought treatment, and severe nursery drought increased gs under stress, when measured in June. No other effects of drought were detected, although drought treatment was effective in increasing survival of planted seedlings. It is suggested that other mechanisms, such as osmotic adjustment, were responsible for the results observed.

34. Driessche, R.v.-d. 1992a. Absolute and relative growth of Douglas-fir seedlings of different sizes. Tree-Physiology 10(2): 141-152.

Keywords: nursery operations
growth

Abstract: Douglas fir (Pseudotsuga menziesii) seedlings of a single (Vancouver Island) seed source were grown in a nursery on Vancouver Island, British Columbia, Canada, for two years to produce five different bare rooted stock types through varying spacing and transplanting treatments: spacing of 1.2, 7.7 and 14.3 cm; 14 cm 1+1 transplant; and 14 cm container transplant. They were then planted in the forest together with one-year-old container seedlings of the same seed source (a sixth treatment). Stem volume mean relative growth rate (Rv) was low immediately after planting for all stock types except the container seedlings, and increased over the following 7.6 years. An 8-week greenhouse test of the six stock types showed that dry weight mean relative growth rate (Rw) generally decreased with seedling dry weight, but this effect was less obvious after planting because only the three smaller stock types showed a decrease in Rw with size. In another experiment, bare root Douglas fir seedlings were grown at five different spacings (1.9, 2.8, 5.0, 7.4 and 10.6 cm) in a nursery for two years, and seedlings from each spacing treatment were sorted into 'large' or 'small' by height. Resulting 10 treatments were outplanted and stem volumes determined over 6.7 years. Effect of nursery spacing on stem volume was

linear up to 3.6 years after planting, but large seedlings had greater stem volume than small seedlings throughout the 6.7 years of the study. There was no indication that Rv decreased with time, but small seedlings had a greater Rv than large seedlings. Relative growth rates of 2-year-old Douglas fir were depressed for a year or two after planting, but then remained relatively constant, or increased during the ensuing 5 years. Relative growth rates of smaller seedlings were greater than those of larger seedlings so that relative biomass differences decreased with time, and the time advantage of larger stock decreased. Absolute size differences increased with time.

OSU Link
Non-OSU Link

35. Driessche, R.v.-d. 1992b. Changes in drought resistance and rootgrowth capacity of container seedlings in response to nursery drought, nitrogen, and potassium treatments. Canadian-Journal-of-Forest-Research 22(5):740-749.

Keywords: nursery operations
nursery fertilization
tree/stand protection
tree/stand health
growth
carbon allocation
tree physiology

Abstract: Douglas fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta), and white spruce (Picea glauca) seedlings, each represented by two seed lots, were grown in Styroblock containers in a greenhouse and plastic shelter house from February 1989 to January 1990. The seedlings were exposed to two N treatments (20 and 200 mg/litre) and three K treatments (5, 25 and 100 mg/litre) arranged factorially within three drought treatments. After winter storage, seedlings from a complete set of treatments were planted into hygric, mesic and xeric sand beds during 12-14 March. Increasing nursery drought stress increased survival of Douglas fir and lodgepole pine after planting, and high N treatment level increased survival of lodgepole pine and white spruce. Under xeric conditions, combined nursery drought and high N treatments increased survival of lodgepole pine by 33%, indicating the importance of nursery cultural regime for stock quality. Increase in nursery drought stress did not decrease seedling size by much; increase in N increased seedling size one season after planting. A positive relation between shoot : root ratio and survival in lodgepole pine and white spruce indicated that increase in N increased both shoot growth and drought resistance over the N range investigated. Only Douglas fir showed an interaction between drought and N treatment and a small response in both survival and dry weight to K application. Root growth capacity, measured at the time of planting, showed an approximate doubling in all species due to high N treatment, and was also increased in white spruce by drought stress. Survival and root growth capacity were poorly correlated, but dry-weight growth in sand beds was well correlated with root growth capacity. Shoot dry weight and percentage N in shoots measured after nursery growth were correlated with root growth capacity. Manipulation of root growth capacity by changing nursery treatment was possible without altering resistance to drought stress after planting.

OSU Link
Non-OSU Link

36. Dunsworth, B.G. 1985. Three-yr survival and height growth of 2+0 bareroot Douglas-fir seedlings treated with a Symbex root dip. Tree-Planters' Notes 36(1): 24-25.

Keywords: nursery operations
nursery fertilization
growth
tree/stand health

Abstract: Seedling roots were dipped in a sol. of Symbex [a stimulant containing fertilizer and microorganisms?] diluted 40:1 with water, or water before planting out in May 1980 on Vancouver Island, British Columbia. Although the ht. growth of Symbex-treated trees was significantly greater in 1981, there were n.s.d. in total ht., ht. growth or survival after 3 growing seasons.

OSU Link
Non-OSU Link

37. Duponnois, R., J. Garbaye, D. Bouchard and J.L. Churin. 1993. The fungus-specificity of mycorrhization helper bacteria (MHBs) used as an alternative to soil fumigation for ectomycorrhizal inoculation of bare-root Douglas-fir planting stocks with Laccaria laccata. Plant and Soil 157:257-262.

Keywords: nursery operations
growth
mycorrhizal response

Abstract: Mycorrhization helper bacteria (MHBs) isolated and selected from the Douglas fir (Pseudotsuga menziesii)-Laccaria laccata symbiotic system have previously been shown to be fungus-specific: they promote ectomycorrhizal establishment of Laccaria laccata but inhibit mycorrhizal formation by other fungi. In this paper, two experiments in a nursery producing 2-yr-old bare rooted Douglas fir planting stock confirmed the specificity of MHBs (9 strains were tested) under field conditions. Mycorrhizal formation by Laccaria laccata, and the closely related L. bicolor was promoted by the specific MHBs tested, but mycorrhizal formation by Hebeloma cylindrosporum and a contaminant white fungus was inhibited; the strain of Paxillus involutus used was only poorly infective and not affected by MHBs. The experiments also showed that, by selectively helping the introduced L. laccata against the resident symbionts, MHBs are an interesting alternative (safer and easier) to soil fumigation for the success of routine controlled mycorrhization of planting stock in forest nurseries. The MHB strain BBc6 (a Pseudomonas fluorescens) is suggested as a suitable candidate for this system.

OSU Link
Non-OSU Link

38. Duryea, M.L. and S.K. Omi. 1987. Top pruning Douglas-fir seedlings: morphology, physiology, and field performance. Canadian-Journal-of-Forest-Research 17(11): 1371-1378.

Keywords: nursery operations
nursery pruning
tree phenology
tree/stand health

growth
yield

Abstract: Seedlings from 9 seed sources at 6 nurseries in Washington, Oregon and California were treated with various pruning treatments including tall and short ht. (25 and 15 cm, respectively), early and late timing (6 wk after bud burst or 6 wk after bud set, respectively), pruning twice or no pruning. Seedlings were evaluated for phenology and quality, and graded in the nursery. For each seed source, seedlings were planted at field sites in their own zone and on one common site. Seedlings pruned tall and early began growing again within 5 wk and set buds 2 wk later than unpruned seedlings. Shippable yield of seedlings pruned tall and early and of unpruned seedlings were n.s.d, although more pruned seedlings had multiple leaders. Pruned seedlings were smaller than unpruned seedlings at the time of planting. Survival and growth were the same for pruned and unpruned seedlings in the 1st year after planting. Pruned seedlings grew more than unpruned seedlings in the 2nd year, but were still shorter after 2 yr. Field growth was greater in seedlings pruned tall or early than in seedlings pruned short or late. It is concluded that pruning should be continued as a cultural practice if it benefits nurseries, but that late short pruning should be avoided.

OSU Link
Non-OSU Link

39. Edgren, J.W. 1981. Field performance of undercut coastal and Rocky Mountain Douglar-fir 2+0 seedlings. Tree-Planters' Notes 32(3): 33-36.

Keywords: nursery operations
tree/stand health
growth

Abstract: Seedlings from 1 seed source each of Pseudotsuga menziesii var. menziesii (coastal) and P. menziesii var. glauca (Rocky Mountain) were grown in a nursery in Washington and half were undercut at 15 cm below the surface at 1-yr-old. Seedlings were lifted in March the next yr (1968) and planted out at 2 sites in Oregon. Survival of undercut coastal firs 3 yr after planting was significantly better than controls. Survival of Rocky Mountain fir was not significantly affected by undercutting. Ht. growth of control seedlings of both varieties was significantly greater in their 1st season than that of undercut seedlings, but the differences disappeared the following year.

OSU Link
Non-OSU Link

40. El Kassaby, Y.A. 1995. Evaluation of the tree-improvement delivery system: factors affecting genetic potential. Tree Physiology 15:545-550.

Keywords: genetic tree improvement
nursery operations
seed orchard management
genetic relationships
reproduction

Abstract: Possible causes of the genetic erosion that occurs during the fragmented phases of the tree-improvement delivery system (a term used for the domestication process in forest trees) are reviewed. The impacts of intentional and unintentional directional selection during phenotypic selection, seed production (with its associated reproductive-phenology asynchrony, fecundity differential and varying propensity to inbreeding), seed processing and storage, and seedling production are evaluated. Allozyme analysis data were used to compare heterozygosity of first-generation seed orchards of western red cedar (Thuja plicata), Sitka spruce (Picea sitchensis) and Douglas fir (Pseudotsuga menziesii) with that of their corresponding natural populations. In general, genetic diversity and heterozygosity parameters of seed orchards are higher or similar to those observed in their natural-population counterparts. However, parental contribution to the resultant seed orchard seed crops is consistently asymmetrical, and this is a major cause of genetic erosion. In most cases, less than 20% of an orchard's clones contribute 80% of the cone crop, thus reducing the effective population size. Because seed germination of coniferous tree species is under strong maternal genetic control, the combined effects of differences in reproductive output and germination, as well as of management practices (e.g., simulated long-term storage of seed showed that loss of viability during storage is genotype specific), cause unintentional directional selection during seedling production. This review confirms the need for genetic monitoring of each phase of the tree-improvement delivery system, so that practical solutions can be developed to alleviate genetic erosion.

OSU Link
Non-OSU Link

41. El Kassaby, Y.A. 2000. Representation of Douglas-fir and western hemlock families in seedling crops as affected by seed biology and nursery crop management practices. Forest Genetics 7(4): 305-315.

Keywords: genetic tree improvement
nursery operations
genetic relationships
tree/stand health
reproduction

Abstract: The impact of container-nursery management practices on the genetic representation of seedling crops of Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) were evaluated. Two experiments, one for each species, were conducted inBritish Columbia, Canada, to determine the cumulative effects of seed-donor variation on germination parameters (percent and speed) and their interaction with container-nursery practices of thinning and culling on the genetic representation of each seed-donor in the resultant seedling crops. The experimental work was conducted on seedlots that were represented with equal contribution of seeds from 15 seed orchard parents (families). In each experiment, a total of 25 920 seeds were sown in four different arrangements to compare the crop development under single-, two-, and three-seeds per cavity (seeds within cavity were selected randomly among the 15 families) and family blocks (seeds within block belonged to one family). This experimental design allowed determination of inter- and intra-family competition. Within each experiment, a total of 15 015 cavities were used and the identity of every seed within every cavity within each arrangement was maintained throughout the study. Families were compared based on: (1) changes in their rank order from seedling emergence (germination) to post-thinning and post-culling status, and (2) relative performance of each family from seed contribution to seedling production. Changes were observed in both assessments (i.e., rank and relative contribution). Path analysis was used to determine the percent contribution of each factor to seedling production. It was determined that

seedling germination, germinant thinning, and seedling culling all affected seedling production, indicating the presence of several consecutive unintentional bottlenecks in the process. Family sowing with culling standards that recognize the growth differences among families in the nursery and single seed sowing after understanding the inter-/intra-family competition are recommended for seedling production to maintain seedling-crop family representation.

OSU Link

42. El Kassaby, Y.A., K. Chaisurisri, D.G.W. Edwards and D.W. Taylor. 1993. Genetic control of germination parameters of Douglas-fir, Sitka spruce, western redcedar, and yellow-cedar and its impact on container nursery production. *In* Dormancy and barriers to germination. Proceedings of an international symposium of IUFRO Project Group P2.04-00 (Seed problems), Pacific Forestry Centre, Victoria, British Columbia, Canada. Ed. D.G.W. Edwards. pp. 37-42.

Keywords: genetic tree improvement
nursery operations
genetic relationships
reproduction

Abstract: The genetic control of germination parameters (germination capacity, peak value, and germination value) in Douglas-fir (Psuedotsuga menziesii (Mirb.) Franco), Sitka spruce (Picea sitchensis (Bong.) Carr.), western redcedar (Thuja plicata Donn), and yellow-cedar (Chamaecyparis nootkatensis (D.Don) Spach.) was studied using wind-pollinated seeds collected from several seed orchards. The extent of genetic control over rhese parameters was assessed through the determination of broad-sense heritabilities. The impact of genetic control of these parameters on the expected genetic diversity of container nursery seedling crops is evaluated.

OSU Link
Non-OSU Link

43. El Kassaby, Y.A. and Y.S. Park. 1993. Genetic variation and correlation in growth, biomass, and phenology of Douglas-fir diallel progeny at different spacings. Silvae-Genetica 42(6): 289-297.

Keywords: genetic tree improvement
nursery operations
genetic relationships
growth
carbon allocation
tree phenology

Abstract: Parents of coastal Douglas fir (Pseudotsuga menziesii) selected from natural stands on sites ranging from 0 to 450 m altitude on Vancouver Island and in southeastern British Columbia were crossed and the resulting 104 full-sib families evaluated for 3 years after germination. The full-sib families were produced by a disconnected diallel mating scheme, consisting of 7 sets of 6-parent partial diallels, grown under 2 spacing treatments in a nursery. The objectives of the study were to determine the extent of genetic control of growth traits, biomass distribution and allocation strategies, and vegetative phenology. Spacing had a significant effect on 6 of the 11 traits studied. Significant GCA

variance was found for all traits except 1-year height. Individual tree narrow-sense heritability varied from 0.06 to 0.69 for root dry weight and vegetative phenology, respectively. Spacing x family interaction variance was significant for only 2 traits. Two harvest indices, based on total and above-ground dry weights, were used to assess dry matter allocation strategy and to explore potential usefulness in tree breeding. Both indices had similar heritability estimates and their genetic correlation was high (0.91), indicating that use of an index based on above ground dry weight is a good surrogate for that based on total dry weight. Genetic correlations among growth and biomass traits were generally high, while those correlations with the harvest indices were variable.

OSU Link
Non-OSU Link

44. El Kassaby, Y.A. and A.J. Thomson. 1996. Parental rank changes associated with seed biology and nursery practices in Douglas-fir. Forest Science 42:228-235.

Keywords: genetic tree improvement
nursery operations
reproduction
genetic relationships
tree/stand health

Abstract: The impact of container-nursery management practices on the genetic composition of seedling crops was evaluated in an experimental study in a seed orchard in British Columbia. The study was designed to determine the cumulative effects of: (1) differences in parental reproductive output in bulk seedlots; (2) parental variation in germination parameters (percentage and speed); and (3) the interaction of these parameters with container-nursery practices of thinning and culling, and their effect on the genetic representation of parents in the resultant seedling crops. Results from the experimental study were compared with predictions of a stochastic simulation designed to estimate the consequences of differential parental seed contribution, and seed germination percentage and germination speed on indicators of crop performance. The experimental study was conducted on a Douglas-fir (Pseudotsuga menziesii) bulk seedlot that was representative of the differential seed contributions from 19 seed orchard parents. The nursery study included a total of 42 000 seeds. Seeds were sown at three seeds per cavity. Within the 14 000 cavities used, the identity of every seed was maintained throughout the study. Comparisons of parents were made based on: (1) changes in their rank order from sowing to postthinning and postculling status; and (2) relative performance from seed contribution to seedling production. Changes were observed in both assessments. Path analysis was used to determine the percentage contribution of each factor to seedling production. It was determined that germination, thinning, and culling contributed 66, 20, and 14%, respectively, to seedling production, indicating the presence of three consecutive bottlenecks in the process. Single seed or individual family sowing in the nursery was recommended for seedling production to maintain genetic diversity.

OSU Link
Non-OSU Link

45. Folk, R.S., S.C. Grossnickle, P. Axelrood and D. Trotter. 1999. Seed lot, nursery, and bud dormancy effects on root electrolyte leakage of Douglas-fir (Pseudotsuga menziesii) seedlings. Canadian-Journal-of-Forest-Research 29(8): 1269-1281.

Keywords: nursery operations
tree physiology
tree/stand health
photosynthesis
growth
tree phenology

Abstract: The effects of seed lot, nursery culture, and seedling bud dormancy status on root electrolyte leakage (REL) of Douglas-fir (Pseudotsuga menziesii) seedlings were assessed to determine if these factors should be considered when interpreting REL for seedling quality. The relationships of REL to survival, net photosynthesis (Pn), stomatal conductance (gwv) mid-day shoot water potential (Psi mid), root growth capacity (RGC), and relative height growth were determined for each factor in experiments in 1994-95 in nurseries inBritish Columbia. Nursery culture had no effect on the relationship between REL and all other measured attributes. Seed lot affected the relationship between REL and Pn, Psi mid, and survival. However, critical REL (i.e., lowest value associated with detectable root damage) and PS80 REL (i.e., level associated with an 80% probability for survival) were similar between seed lots. Bud dormancy status affected the relationship between REL and survival, RGC, and relative height growth. Control levels of REL, critical REL, and PS80 REL decreased as the number of days required for 50% terminal bud break declined. Thus, terminal bud dormancy status must be known before REL can be used to assess seedling quality. If the bud dormancy status of Douglas-fir populations is known, then critical and PS80 REL levels may be useful as indices of root damage.

OSU Link
Non-OSU Link

46. Frey Klett, P., J.L. Churin, J.C. Pierrat and J. Garbaye. 1999. Dose effect in the dual inoculation of an ectomycorrhizal fungus and a mycorrhiza helper bacterium in two forest nurseries. Soil Biology and Biochemistry 31:1555-1562.

Keywords: nursery operations
growth
carbon allocation
mycorrhizal response
soil properties

Abstract: Disinfected soil at two Douglas-fir (Pseudotsuga menziesii) bare-root forest nurseries was inoculated with three doses (8 X105, 8 X107 and 8 X109 cfu [colony forming units]/m2) of the rifampicin-resistant mycorrhiza helper bacterium Pseudomonas fluorescens strain BBc6R8 and the ectomycorrhizal fungus Laccaria bicolor strain S238N. In one of the two nurseries, two doses of fungal inoculum (50 and 100 mg/m2 dry weight (DW) mycelium entrapped in alginate beads at the constant dose of 1 litre/m2) were tested. For all bacterial treatments the density of P. fluorescens BBc6R8 in the soil, determined by dilution plating, dropped below the detection limit (10-2 cfu/g DW soil) 2 weeks after inoculation. Fifteen weeks after inoculation, the introduced bacterium was detected by enrichment only in the treatments inoculated with the highest bacterial dose. Two years after inoculation, P. fluorescens BBc6R8 was not detected in the soil of any of the bacterial treatments. Five months after inoculation and sowing, bacterial inoculation significantly increased the percentage of mycorrhizal short roots on plants inoculated with either low or high amounts of L. bicolor, in one of the nurseries. The lowest bacterial dose increased mycorrhizal colonization from 45 to 70% in plants

inoculated with the low amount of fungal inoculum, and from 64 to 77% in plants inoculated with the high amount of fungal inoculum. The lowest bacterial dose increased mycorrhizal colonization more than the highest bacterial dose. The same L. bicolor mycorrhizal index (70%) was obtained with 50 mg/m2 DW mycelium plus the bacterium than with twice this fungal dose and no bacterium (64%). Two years after inoculation, the height of the mycorrhizal Douglas-firs in the other nursery was significantly increased by the lowest bacterial dose (from 40.7 to 42.6 cm). It was indicated that co-inoculating a helper bacterium together with an ectomycorrhizal fungus is an efficient way to optimize controlled mycorrhization techniques for the production of high-quality Douglas-fir planting stocks. It was confirmed that BBc6R8 acts at a low population density (less than 10-2 cfu/g soil), this contrasts with most PGPR [plant growth promoting rhizobacteria?] effects where the minimal inoculation dose of 105 cfu/g soil is required to obtain the beneficial effect.

OSU Link
Non-OSU Link

47. Gagnon, J., C.G. Langlois, D. Bouchard, F.l. Tacon and F. Le Tacon. 1995. Growth and ectomycorrhizal formation of container-grown Douglas-fir seedlings inoculated with Laccaria bicolor under four levels of nitrogen fertilization. Canadian Journal of Forest Research 25:1953-1961.

Keywords: nursery operations
nursery fertilization
growth
carbon allocation
tree physiology
tree morphology
mycorrhizal response
soil properties

Abstract: Container-grown Douglas fir (Pseudotsuga menziesii) seedlings were inoculated at the time of sowing with a Laccaria bicolor mycelial suspension produced in a fermentor. They were grown in a peat moss-vermiculite substrate under four levels of N fertilization (7.2, 14.4, 21.6 and 28.7 mg/seedling per season (N1, N2, N3 and N4, respectively)) to determine the N level suitable for both ectomycorrhizal development and seedling growth. After 18 weeks in the greenhouse, seedlings inoculated with L. bicolor had 44%, 32%, 44% and 5% of their short roots mycorrhizal when fertilized with N1, N2, N3 and N4, respectively. Only when they were fertilized with N4 did the L. bicolor seedlings have significantly greater shoot height than the controls. For the other growth parameters, they were not significantly different from control seedlings for any of the N levels. After 18 weeks, regardless of the level of N, seedlings inoculated with L. bicolor had significantly lower N concentrations (%) and contents (mg/seedling) than the uninoculated ones. Consequently, for the same production of biomass, the mycorrhizal seedlings had taken up less N than the nonmycorrhizal ones. The efficiency of applied N, expressed in terms of produced biomass, decreased when the N fertilization increased; mycorrhizal and nonmycorrhizal seedlings did not tend to be different. The efficiency of the absorbed N also decrease with the level of applied N, but less rapidly, and tended to be greater for the mycorrhizal seedlings than for the nonmycorrhizal ones. Therefore, the mycorrhizal infection improved the utilization of the absorbed N. N3 was the best of the four N levels used, since it was the only one that maximized both the ectomycorrhizal formation and the growth of the seedlings. In other words, a total seedling N concentration of 1.6% and a substrate fertility of 52 p.p.m. N are appropriate to optimize both the ectomycorrhizal development and the growth of Douglas fir seedlings.

OSU Link
Non-OSU Link

48. Graff, J.E., Jr., R.K. Hermann and J.B. Zaerr. 1999a. Dry matter and nitrogen allocation in western redcedar, western hemlock, and Douglas fir seedlings grown in low- and high-N soils. Annals-of-Forest-Science 56(7): 529-538.

Keywords: nursery operations
nursery fertilization
growth
tree physiology

Abstract: Seedlings of western red cedar (Thuja plicata), western hemlock (Tsuga heterophylla), and Douglas fir (Pseudotsuga menziesii) were transplanted into each of 48 pots with soils of low or high levels of available NO3- (and total N) and assigned to one of four treatments: unamended control; amendment with 60 mg kg-1 (NH4)2SO4; amendment with 15 mg kg-1 of the nitrification inhibitor dicyandiamide (DCD) or amendment with both (NH4)2SO4 and DCD. Dry weight and N content increments of seedling tissues were determined after 8 weeks. Seedlings grown on the low-N soil accumulated 65 % of the dry matter and 40 % of the N accumulated by seedlings grown on the high-N soil. Retranslocation of N from year-old foliage and the stem/branch components of western red cedar and Douglas fir, but not western hemlock, was an important source of N for current-year foliage and roots of low-N-grown seedlings. Western hemlock achieved the greatest relative dry-matter increment (Loge(DMfinal) - Loge(DMinitial); RDMI) and relative N increment (Loge(Nfinal) - Loge(Ninitial); RNI) in each soil and accumulated 35 % more N from the low-N and 10 % more N from the high-N soils than the other species. The RDMI of western red cedar was intermediate between that of western hemlock and Douglas fir, whereas its RNI on each of the soils was lowest. The results suggest that western hemlock is more efficient than western red cedar or Douglas fir in acquiring inorganic N, especially from low-N soils.

OSU Link
Non-OSU Link

49. Haase, D.L. and R. Rose. 1993. Soil moisture stress induces transplant shock in stored and unstored 2+0 Douglas-fir seedlings of varying root volumes. Forest-Science 39(2): 275-294.

Keywords: nursery operations
tree/stand protection
growth
tree morphology

Abstract: Transplant stock was induced by applying a range of soil water contents (6, 12, 18 or 24%) to unstored and cold-stored 2-yr-old (2 + 0) bareroot Douglas fir (Pseudotsuga menziesii) seedlings graded by root volume. Moisture stress had the greatest influence on morphological characteristics that express transplant shock. Seedling terminal shoot growth, stem diameter growth, and needle length increased with increased soil moisture content. In addition, number of needles per centimeter on the terminal shoot greatly increased with increasing drought stress. Under high drought stress, seedlings with relatively high root volumes tended to exhibit reduced early growth, but later showed significantly increased overall growth regardless of soil water content. In every case, seedlings grown in the driest

soil had the lowest dry weight components. Similarly, seedlings with the smallest initial root volumes had the lowest dry weights, and those with the largest root volumes had the greatest dry weights. The results indicate that drought stress is a cause of transplant shock, and that increased seedling root volume may enable seedlings to avoid shock following outplanting to a specific site.

OSU Link
Non-OSU Link

50. Haase, D.L. and R. Rose. 1994. Effects of soil water content and initial root volume on the nutrient status of 2+0 Douglas-fir seedlings. New-Forests 8(3): 265-277.

Keywords: nursery operations
tree/stand protection
tree physiology
growth
tree morphology

Abstract: Two-year-old bareroot Douglas fir (Pseudotsuga menziesii) seedlings from a NW Oregon provenance were graded on the basis of four root-volume categories - 5 to 8, 9 to 10, 11 to 13, and 14 to 20 cmsuperscript 3 - and transplanted into pots and subjected to one of four moisture-stress treatments (6, 12, 18, and 24% soil water content) for 16 weeks. Macronutrient concentrations and contents of both old (i.e. nursery-grown) and new (i.e. grown during moisture stress treatment) foliar tissue were determined. A reduction in soil water content resulted in high concn of phosphorus, potassium, and particularly nitrogen in both old and new foliar tissue. This was attributed to reduced growth, translocation, metabolic activity, and nutrient requirement in response to moisture stress. Seedlings with relatively greater root volumes exhibited higher nutrient concn and contents, as well as increased growth. Thus, increased total root biomass per unit of soil area with increasing seedling root volume may have resulted in greater nutrient use, supply, uptake, and storage. It is suggested that relations between initial root volume and water stress can be applied to nursery cultural practices in order to increase seedling adaptation to a specific stress.

OSU Link
Non-OSU Link

51. Haase, D.L. and R. Rose. 1998. Ten years of herbicide testing in PNW forest nurseries. *In* Proceedings of the Annual Meeting of the Western Society of Weed Science, Waikoloa, Hawaii, 10-12 March, 1998. pp. 50-52.

Keywords: nursery operations
tree/stand health

Abstract: Nursery trials were conducted in Oregon in 1987-96 to investigate the level of weed control and phytotoxicity of herbicides applied to Douglas fir (Pseudotsuga menziesii), noble fir (Abies procera), lodgepole pine (Pinus contorta), ponderosa pine (P. ponderosa), western hemlock (Tsuga heterophylla), Pacific yew (Taxus brevifolia), red alder (Alnus rubra) and bitterbrush (Picramnia pentandra) seedlings. Results indicated that lactofen, metolachlor and clethodim gave good weed control and caused little phytotoxicity. Notably, clethodim did not damage T. heterophylla. Oxadiazon caused phytotoxic

symptoms at high but not low concentrations. However, clopyralid, isoxaben, pendimethalin, prodiamine and thiazopyr were deemed unsuitable for some or all species in nurseries on the basis of phytotoxic damage recorded in these and other trials.

OSU Link
Non-OSU Link

52. Haase, D.L., J. Trobaugh and R. Rose. 1999. Douglas-fir container stock grown with fertilizer-amended media: some preliminary results. Rocky Mountain Research Station, USDA Forest Service National Proceedings: Forest and Conservation Nursery Associations 1999, 2000, and 2001. RMRS P-24. 31-32 pp.

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

Abstract: This paper presents the initial results of a study conducted in a nursery in Oregon, USA, to quantify the response of container grown Douglas-fir (Pseudotsuga menziesii) seedlings to various fertilizer treatments (Simplot's 13-13-13 and 17-5-11, and Scotts Company's 18-5-12 and 15-9-10) in terms of height, stem diameter and foliar nutrient content.

53. Haglund, W.A., K.W. Russell and R.C. Holland. 1981. Moss control in container-grown conifer seedlings. Tree-Planters' Notes 32(3): 27-29.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: Seedlings grown in styroblock containers were sprayed with 8 surfactants, or combinations of surfactant and the fungicide captan. Phytotoxicity and moss control were recorded 7 and 14 days after treatment and trees were measured after 30-60 days. The least phytotoxic surfactant was X77; this had no significant effect on ht., stem diam. and total wt. of Pseudotsuga menziesii or Tsuga heterophylla seedlings. Almost complete moss control was achieved with 40-80 lb captan and 2.5-10 gal X77 in 100 gal water applied to Abies procera seedlings; treatment with the highest concn. (80 lb captan and 10 gal X77) was only phytotoxic when the seedlings already had foliar injury. In Tsuga heterophylla treatment with captan and X77 at various concn. caused tree injury only at 80-90 degrees F, but not at 60-65 degrees F.

OSU Link
Non-OSU Link

54. Hahn, P.F. and A.J. Smith. 1983. Douglas-fir planting stock performance comparison after the third growing season. Tree-Planters' Notes 34(1): 33-39.

Keywords: nursery operations

planting operations
growth
tree/stand health

Abstract: Three types of containerized (40, 75 or 125 cmsuperscript 3 containers) and bare rooted (2+1, 3+0 and plug-1 stock) seedlings were planted out in Oregon in Feb. 1979 on N. and S. facing slopes, clear felled in 1978. In general, containerized seedlings showed superior survival rates and greater height growth - particularly on the harsh S. slope, and lower reforestation costs. The 75-cmsuperscript 3 containerized seedlings are recommended, except for N. facing and wet coastal areas, where brush competition can be severe shortly after planting. In such areas, taller bare-rooted seedlings performed better.

OSU Link
Non-OSU Link

55. Hamm, P.B., S.J. Cooley and E.M. Hansen. 1984. Response of Phytophthora spp. to metalaxyl in forest tree nurseries in the Pacific Northwest. Plant-Disease 68(8): 671-673.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: In tests on Douglas fir (Pseudotsuga menziesii) at 2 commercial forest tree nurseries in Ore., 1 application of Subdue (metalaxyl) suppressed root rot. Of 3 P. spp. isolated from treated seedlings (P. megasperma, P. drechsleri and P. pseudotsugae), only P. pseudotsugae decreased in isolation frequency because of the fungicide. Survival of P. spp. in infected seedlings remained high after treatment. At 1 nursery, 10 months after the first application, P. spp. were isolated from 92% of the seedlings across fungicide treatments, whereas at the 2nd isolation frequencies from seedlings were 77, 70, 29 and 13%, respectively, after 0, 1, 2 and 3 applications. P. was recovered from previously healthy seedlings 8 wk after they were transplanted into naturally infested, metalaxyl-treated soil.

OSU Link
Non-OSU Link

56. Helgerson, O.T. 1985. Survival and growth of planted Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and ponderosa pine (Pinus ponderosa Dougl. ex Laws.) on a hot, dry site in southwest Oregon. Tree-Planters' Notes 36(4): 3-6.

Keywords: nursery operations
planting operations
tree/stand health
growth

Abstract: One-yr-old containerized seedlings and 2-yr-old bare rooted seedlings of both species were planted in Feb. 1982 on a W.-facing 35% slope on Tin Pan Peak. The site receives <760 mm of precipitation annually. Weeds were controlled with herbicides applied before and after planting. Survival after 2 yr averaged 94% for all stock types; survival of bare rooted seedlings (98-99%) was

significantly better than that of containerized seedlings (88-92%). Relative vol. growth was greater for pine than Douglas fir. After 2 yr, the 2+0 bare rooted pines were significantly larger than the 2+0 Douglas firs, despite a smaller starting size.

OSU Link
Non-OSU Link

57. Helgerson, O.T. 1990b. Response of underplanted Douglas-fir to herbicide injection of sclerophyll hardwoods in southwest Oregon. Western-Journal-of-Applied-Forestry 5(3): 86-89.

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

Abstract: Low-value broadleaf sclerophyll forests in SW Oregon, typically composed of tanoak (Lithocarpus densiflorus), Pacific madrone (Arbutus menziesii) and chinkapin (Castanopsis chrysophylla), may be converted to commercially valuable Douglas fir (Pseudotsuga menziesii) by underplanting. Results are given of studies of container-grown plug and nursery-grown bareroot fir seedlings planted out in March 1983 on plots in which all broadleaf stems had been previously (September 1981) injected with triclopyr amine. Although 60% broadleaf cover was killed by injection, 7 years later ground cover was significantly greater on these treated plots because of sprouting. Seedlings planted beneath treated broadleaf trees experienced greater daytime, but less predawn, moisture stress; plugs survived better than bareroots; and survival of seedlings on treated plots was not significantly better until 2 years after planting. Herbicide injection also resulted in increased height, diameter and volume growth rates of Douglas fir seedlings, and is recommended for the establishment of a conifer stand.

OSU Link
Non-OSU Link

58. Helgerson, O.T., S.D. Tesch, S.D. Hobbs and D.H. McNabb. 1989. Survival and growth of ponderosa pine and Douglas-fir stocktypes on a dry low-elevation site in southwest Oregon. Western-Journal-of-Applied-Forestry 4(4): 124-128.

Keywords: nursery operations
planting operations
growth
tree/stand health

Abstract: Two stocktypes (1+0 container-grown plugs and 2+0 nursery-grown bareroots) of ponderosa pine (Pinus ponderosa) and of Douglas fir (Pseudotsuga menziesii) were planted on a hot, droughty, low-altitude site near Medford, Oregon, which had burned in 1981. The main objective was to assess the potential for reforesting this type of site. After 5 growing seasons, bare rooted stock survived (98%) significantly better than plugs (89%); survival did not differ significantly by species. Douglas fir was taller

than pine, pine was larger in diam., and the 2 species had approximately equal stem volumes. Bare rooted stock was consistently larger than plugs. Results show that these species and stocktypes can provide good reforestation after 5 yr on this type of site when seedlings are of good quality, are planted properly, and are given good weed control.

OSU Link
Non-OSU Link

59. Helgerson, O.T., S.D. Tesch, S.D. Hobbs and D.H. McNabb. 1992. Effects of stocktype, shading, and species on reforestation of a droughty site in southwest Oregon. Northwest-Science 66(2): 57-61.

Keywords: nursery operations
planting operations
tree/stand protection
tree/stand health
growth

Abstract: On hot, dry sites, shading may differentially increase survival of planted Douglas fir (Pseudotsuga menziesii) according to seedling size, and Douglas fir may differ from ponderosa pine (Pinus ponderosa) in early survival and growth. The survival and growth of Douglas fir seedlings (1+0 container-grown plugs and 2+0 bare-rooted seedlings, unshaded or shaded with cardboard shadecards at planting) and unshaded 2+0 bare-rooted ponderosa pine were compared on a droughty south facing clear felling in Oregon. The site was clear felled and burned in 1982 and the seedlings were planted in 1983. Shading did not significantly increase survival of plugs, possibly because of a wetter than normal first summer, nor did shading affect growth of either Douglas fir stocktype 5 yr after planting. Bare-rooted Douglas fir remained significantly larger than plugs, but relative growth rates for the initially smaller plugs were significantly greater for diameter and volume. Survival and growth of ponderosa pine tended to be better than those of Douglas fir. It was concluded that both species appeared to be suitable for reforestation after clear felling on sites subject to drought.

OSU Link
Non-OSU Link

60. Henry, C.L. 1987. Growth response, mortality, and foliar nitrogen concentrations of four tree species treated with pulp and paper and municipal sludges. *In* The-forest-alternative-for-treatment-and-utilization-of-municipal-and-industrial-wastes. *Eds.* Cole, D.W., C.L. Henry, and W.L. Nutter. University of Washington Press, Seattle, Washington, USA. pp. 258-265.

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

Abstract: Four nursery beds at the University of Washington Charles Lathrop Pack Demonstration Forest were each divided into plots that received 8 sludge treatments before being planted with seedlings of

Douglas fir, Abies procera or Pinus monticola, or cuttings of Populus deltoides X P. trichocarpa. Each sludge and the unamended soil were analysed for total solids, total C, P and K, total N and NH4-N. Ht. and diam. were measured after planting in April 1984 and again in Feb. 1985. N was determined in foliage sampled during Oct. (Populus) or Feb. (other species). Addition of pulp and paper sludge alone and combined with municipal sludge provided predictable growth responses when compared with the C : N ratio of each treatment. Av. response was positive when the C : N ratio was more favourable than that of untreated soil, but av. response was negative when soil was treated with primary pulp and paper sludge with a very high C : N ratio. Treatments that produced the greatest growth also increased seedling mortality.

Non-OSU Link

61. 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

62. 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

63. Hildebrand, D.M., J.K. Stone, R.L. James and S.J. Frankel. 2004. Alternatives to preplant soil fumigation for Western forest nurseries. Pacific-Northwest-Research-Station,-USDA-Forest-Service General-Technical-Report PNW-GTR-608. ii + 27 p.

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

Abstract: Field trials were conducted at six bare-root forest tree (Pinus ponderosa, Pseudotsuga menziesii, Pinus contorta and Abies magnifica var. shastensis) nurseries in the Western United States: Bend Pine Nursery in Bend and J. Herbert Stone Nursery in Central Point (Oregon), Coeur d'Alene Nursery and Lucky Peak Nursery in Idaho, and Humboldt Nursery near McKinleyville and Placerville Nursery near Camino (California). These field experiments compared cultural treatments including timing and depth of sowing; bare fallow (with and without periodic tilling); organic amendments including sawdust, composts, and cover crops; mulches including pine needles, sawdust, and rice straw; and fumigation with methyl bromide/chloropicrin or dazomet. Measured effects included population levels of potential soil-borne pathogens (species of Fusarium and Pythium), disease incidence, seedbed density, and sizes of conifer seedlings. Several non-fumigation treatments resulted in production of seedlings with densities and sizes similar to or better than those produced in beds treated with chemical fumigation. Results varied within the nurseries depending on conifer species, field history, and disease

presence. Beneficial cultural practices included: (1) incorporation of slowly decomposing organic soil amendments, e.g., aged sawdust with additional nitrogen provided later to seedlings; (2) bare fallowing with periodic tilling, and bare fallowing without periodic tilling plus supplemental weed control; and (3) sowing of conifer seed earlier and more shallow than sown conventionally, and covering seed with a nonsoil mulch such as aged sawdust or hydromulch.

OSU Link
Non-OSU Link

64. Hobbs, S.D., S.G. Stafford and R.L. Slagle. 1987. Undercutting conifer seedlings: effect on morphology and field performance on droughty sites. Canadian-Journal-of-Forest-Research 17(1): 40-46.

Keywords: nursery operations
tree morphology
growth
tree/stand health

Abstract: One-yr-old barerooted Douglas fir and ponderosa pine seedlings in an Oregon nursery were subjected during Feb.-June 1980 to 5 undercutting treatments that varied by number and depth of cuts and seedling phenology at time of treatment. Eight morphological variables were measured in Jan. 1981 before planting the seedlings at 2 sites in Oregon. Seedling survival and growth was recorded annually for 4 yr. All treatments significantly reduced shoot growth in the nursery, but changes in root system morphology depended on treatment severity and species. Treatment effects were generally more pronounced in ponderosa pine than in Douglas fir. Discriminant analysis showed that seedlings responded similarly in all undercutting treatments relative to control seedlings that were not undercut. No effects of undercutting were apparent after 4 yr in the field.

OSU Link
Non-OSU Link

65. Hobbs, S.D. and K.A. Wearstler, Jr. 1983. Performance of three Douglas-fir stocktypes on a skeletal soil. Tree-Planters' Notes 34(3): 11-14.

Keywords: nursery operations
tree/stand health
growth

Abstract: Plug-1 bare rooted seedlings, initially grown in containers and transplanted to a nursery for 1 yr, 2-0 bare rooted seedlings and 1-0 plug stock were planted on a steep, severe site in the Siskiyon Mts., SW Oregon, in 1980. Height and diameter were recorded after planting and in the autumn in 1980 and 1981. Survival was 91% for 1-0 plug seedlings, 87% for plug-1 seedlings and 56% for 2-0 bare rooted stock. There were n.s.d. in height and diameter growth.

OSU Link
Non-OSU Link

66. Hung, L.L.L. and R. Molina. 1986. Use of the ectomycorrhizal fungus Laccaria laccata in forestry. III. Effects of commercially produced inoculum on container-grown Douglas-fir and ponderosa pine seedlings. Canadian-Journal-of-Forest-Research 16(4): 802-806.

Keywords: nursery operations
mycorrhizal response

Abstract: In greenhouse experiments, a commercial vegetative inoculum of L. laccata formed ectomycorrhizas on both Douglas fir and ponderosa pine. In trials at container nurseries at Lebanon, Oregon, L. laccata successfully formed ectomycorrhizas on Douglas fir, but roots of ponderosa pine seedlings were heavily contaminated with Thelephora sp. It is concluded that commercially produced inoculum of L. laccata can be used operationally in container nurseries, though further tests are needed to assess the competitive effect of Thelephora sp. and the performance of inoculated seedlings after planting in the field.

OSU Link
Non-OSU Link

67. Hung, L.L.L. and J.M. Trappe. 1987. Ectomycorrhizal inoculation of Douglas-fir transplanted container seedlings with commercially produced inoculum. New-Forests 1(2): 141-152.

Keywords: nursery operations
mycorrhizal response
growth

Abstract: Commercially produced vegetative inocula of Laccaria laccata and Hebeloma crustuliniforme successfully formed ectomycorrhizae with Douglas fir transplanted container (plug + 1) seedlings. After 4.5 months in containers, 83% and 90%, respectively, of short roots were mycorrhizal. L. laccata- or H. crustiliniforme-inoculated seedlings had significantly more mycorrhizal and total short roots than Pisolithus tinctorius-inoculated (4% mycorrhizal root tips) or uninoculated control seedlings. No significant differences were detected in seedling growth at the end of the container phase. After transplantation and growth in nursery beds for 17 months, mean new short root colonization of all seedlings was 80%. H. crustuliniforme persisted as a dominant mycorrhizal fungus on seedlings initially inoculated with this fungus. L. laccata-inoculated seedlings had 40% of their short roots colonized by L. laccata and another 40% by the native fungi Rhizopogon and Thelephora spp. All mycorrhizae of control seedlings and those inoculated with P. tinctorius were formed by fungi native to the nursery beds. A significant fungal treatment effect was detected for shoot height only. Control seedlings were significantly taller than L. laccata-inoculated seedlings after transplanting.

OSU Link
Non-OSU Link

68. Jacobs, D.F., R. Rose and D.L. Haase. 2003a. Development of Douglas-fir seedling root architecture in response to localized nutrient supply. Canadian-Journal-of-Forest-Research 33(1): 118-125.

Keywords: nursery operations
nursery fertilization

tree morphology
tree physiology
growth

Abstract: Three months following sowing, Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedlings were transplanted into pots with controlled-release fertilizer (CRF) applied at rates of 0, 8, 16, and 24 g/2200 cm3 soil as a single uniform layer beneath the root system. Seedlings were destructively harvested periodically, and roots were divided into vertical segments above (S1), within (S2), and below (S3) the fertilizer layer. Two months following transplant, the number of active root tips was positively correlated with CRF rate in S1 and negatively correlated with rate in S2 and S3. At 6 months, root penetration into S3 was severely restricted at 16 and 24 g. This was attributed to detrimental changes in soil osmotic potential in S2. Fertilizer improved seedling growth at 8 g after 6 months compared with controls but was inhibitory at 24 g. Photochemical quantum yield was higher in all CRF treatments compared with controls 3 months following transplant, which corresponded with rapid initial CRF nutrient release. Despite improvements in nutrient release technology with CRF, high application rates may result in excessive concentrations of fertilizer nutrients in media, which can restrict root penetration and negatively affect seedling growth. Conservative application rates and improvements in CRF technology will help reduce the potential for adverse effects on seedling development.

OSU Link
Non-OSU Link

69. 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

70. Joseph, G. and R.G. Kelsey. 1999. Growth of Douglas-fir and ponderosa pine seedlings with foliar applications of methanol and ethanol. Western-Journal-of-Applied-Forestry 14(4): 183-185.

Keywords: nursery operations
growth
tree morphology
tree/stand health

Abstract: Ethanol and methanol have been reported to enhance the growth and development of several agricultural and horticultural species. To test whether methanol or ethanol stimulated growth of coast Douglas fir (Pseudotsuga menziesii var. menziesii) or ponderosa pine (Pinus ponderosa)in the nursery, seedlings were sprayed with concentrations of 1 to 10% (v/v) on the foliage twice a week for 13 wk during the growing season. Foliar applications of methanol and ethanol neither significantly stimulated nor inhibited growth, and signs of damage at these concentrations were lacking.

OSU Link
Non-OSU Link

71. Kamm, J.A., P.D. Morgan, D.L. Overhulser, L.M. McDonough, M. Triebwasser and L.N. Kline. 1983. Management practices for cranberry girdler (Lepidoptera: Pyralidae) in Douglas-fir nursery stock. Journal-of-Economic-Entomology 76(4): 923-926.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: Chrysoteuchia topiaria (Zell.), a known pest of grasses and cranberries, was shown in field-plot studies in Oregon and Washington State in 1980-81 to be a pest of seedlings of Douglas fir (Pseudotsuga menziesii) grown in nurseries. The pyralid was capable of reproduction in nursery beds where feeding larvae partially or completely girdled the taproot of seedlings. Pheromone-trap collections indicated that grasslands bordering nurseries and not nursery beds were the primary source of adults. In addition to Douglas fir, several species of true fir were damaged by larvae, but no feeding damage was observed on pine, cedar, hemlock or spruce. Insecticides applied to control adults and larvae effectively reduced the incidence of damage. It was suggested that, when possible, a pest management programme should include grasslands bordering the nursery, control of weeds and the use of a non-food-plant cover crop in the nursery.

OSU Link
Non-OSU Link

72. Kaya, Z. 1992. The effects of test environments on estimation of genetic parameters for seedling traits in 2-year-old Douglas-fir. Scandinavian-Journal-of-Forest-Research 7(3): 287-296.

Keywords: genetic tree improvement
nursery operations
genetic relationships
growth
tree phenology

Abstract: The effects of test environments (dry versus wet) on the estimation of genetic parameters in seedling traits were studied in 160 open-pollinated families of Douglas fir (Pseudotsuga menziesii) from southwestern Oregon. Seedlings from four populations were grown in two test nursery environments between which a water potential difference of -9 bars was created over two growing seasons, by withholding water for 4 and 8 wk, respectively. Estimated genetic variances in most growth and phenology traits were considerably higher for seedlings grown in the wet environment than for those in the dry. Estimated genetic correlations between the same traits measured in different test environments indicated that most seedling traits studied for two growing seasons were genetically stable in both environments, suggesting that genotype environment interaction in these traits are weak. However, it is emphasized that the effect of test environment on estimation of genetic parameters in seedling traits, especially in adaptive seedling traits, should be evaluated very carefully when early evaluation of genetic entries is practised in Douglas-fir, since these traits (budburst timing, lammas growth and free growth) appear to be plastic in character.

73. Kelsey, R.G., G. Joseph and E.A. Gerson. 1998. Ethanol synthesis, nitrogen, carbohydrates, and growth in tissues from nitrogen fertilized Pseudotsuga menziesii (Mirb.) Franco and Pinus ponderosa Dougl. ex Laws. seedlings. Trees: Structure and Function 13(2): 103-111.

Keywords: nursery operations
nursery fertilization
tree physiology

Abstract: Seedlings of Douglas fir (Pseudotsuga menziesii) and ponderosa pine (Pinus ponderosa) were grown in a controlled environment and given nutrient solutions containing 0 (-N) or 150 ppm nitrogen (+N). Seedling growth, and the concentrations of N and carbohydrates in their tissues were affected by the treatments. Metabolically active tissues, such as roots, incubated with a limited supply of O2 became hypoxic faster and synthesized more ethanol than less active tissues, such as needles. All tissues that were incubated for 4 h in N2 synthesized ethanol. Needles incubated in N2 and light had much lower quantities of ethanol than needles in N2 and dark, suggesting that O2 from photosynthesis limited internal anoxia. Most tissues from +N seedlings synthesized greater quantities of ethanol in N2 anoxia than tissues from -N seedlings, probably because they were able to produce more enzymes with a greater availability of N. However, this increase in ethanol synthesis between N treatments was most pronounced in the phloem. Ethanol and soluble sugar concentrations were negatively related in needles and positively related in roots of +N seedlings, but not -N seedlings. Starch concentrations had no effect on the amount of ethanol produced by any tissue. Regardless of N treatments, all tissues from ponderosa pine produced more N2-induced ethanol than Douglas-fir, in part because its tissues

contained different concentrations of soluble sugars and N as a consequence of phenological differences between the species. However, ponderosa pine tissues may also maintain greater quantities of anaerobic enzymes, or their isoenzymes than Douglas fir.

OSU Link
Non-OSU Link

74. Khan, S.R., R. Rose, D.L. Haase and T.E. Sabin. 1996. Soil water stress: its effects on phenology, physiology, and morphology of containerized Douglas-fir seedlings. New-Forests 12(1): 19-39.

Keywords: nursery operations
growth
tree physiology
tree phenology

Abstract: Containerized 3-month-old Douglas fir (Pseudotsuga menziesii) seedlings were subjected to six moisture-stress treatment (ranging from 7 to 65% soil water content by volume) for 12 weeks. At the end of this period, there were significant differences in phenological, physiological, and morphological responses among the seedlings in the various moisture-stress treatments. In general, seedlings grown under very high or very low soil moisture conditions were adversely affected, while those grown under moderate conditions (29 to 53% water content) exhibited optimum growth, bud development, and nutrient and starch reserves. The use of vector analysis was found to be helpful in data interpretation. The results indicate the importance of closely monitoring nursery moisture regimes in order to achieve the best seedling quality.

OSU Link
Non-OSU Link

75. Krakowski, J. and Y.A. El-Kassaby. 2003. Effects of stratification and simulated aging on germination of Douglas-fir seed from a clonal seed orchard. Forest-Genetics 10(1): 65-70.

Keywords: nursery operations
tree/stand health
reproduction

Abstract: Seeds from 15 Douglas-fir (Pseudotsuga menziesii) clones were germinated in a factorial design with two pre-treatments (unstratified and stratified) and seven simulated aging periods (0, 2, 4, 7, 10, 12 and 14 days). Simulated aging consisted of high temperature (40 degrees C) and relative humidity (100%) exposure, which simulates physiological stresses and consequent deterioration in long-term storage. Seed deteriorated as aging treatments lengthened; no germination occurred after 12 days. Germination parameters (capacity, peak value, speed, completeness) were calculated, and pre-treatment and aging effects evaluated using a mixed model analysis of variance. Germination completeness and speed were higher after two days of aging for stratified seed, whereas only peak value increased for unstratified seed. After four days aging, all parameters decreased. Two days of aging enhanced germination capacity of unstratified seed by 15%, but stratified seed was still 13% higher. Douglas-fir seed should be stratified before germination, but unstratified seed can be exposed to 40 degrees C and 100% humidity for two days to augment seedling stock during the growing season. Ex situ

Douglas-fir genetic resource conservation, as well as more adequate representation of planted genotypes across the landscape, can benefit from two days of aging, which would ensure slowly-germinating genotypes are represented in the population.

OSU Link

76. Lavender, D.P. and S.G. Stafford. 1985. Douglas-fir seedlings: some factors affecting chilling requirement, bud activity, and new foliage production. Canadian-Journal-of-Forest-Research 15(2): 309-312.

Keywords: nursery operations
tree/stand health
tree physiology
tree phenology

Abstract: Potted 2-yr-old seedlings were exposed to a range of natural and artificial environments at the Forest Research Laboratory, Oregon State University during the autumn and winter before a 9-wk period in an environment designed to permit active shoot growth. Seedling response demonstrated (i) that exposure to a period of short (9 h), mild (20 degrees C) days prepared seedlings for the beneficial effects of subsequent chilling (4.4 degrees C) temperatures and (ii) that the physiology of dormancy of Douglas-fir seedlings may be adversely affected by environments that differ markedly from those prevailing in the Pacific Northwest during the autumn.

OSU Link
Non-OSU Link

77. Litvak, M.E., J.V.H. Constable and R.K. Monson. 2002. Supply and demand processes as controls over needle monoterpene synthesis and concentration in Douglas fir [Pseudotsuga menziesii (Mirb.) Franco]. Oecologia 132(3): 382-391.

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

Abstract: We measured the relative control that resource availability (as a supply-side control) and wounding (as a demand-side control) exert on patterns of monoterpene synthesis and concentration in Douglas fir [Pseudotsuga menziesii (Mirb.) Franco] needles. While supply-side controls should alter monoterpene production due to changes in the availability of substrate (carbohydrates), demand-side controls alter the need for a defensive product. We examined these relationships by measuring constitutive (preformed) and wound-induced rates of monoterpene synthesis and pool sizes in trees grown under ambient and elevated (ambient +200 micro mol mol-1) CO2, ambient and elevated (ambient +4 degrees C) temperature, and in trees grown under four levels of nitrogen fertilization (0, 50, 100 and 200 micro g g-1 N by weight). Monoterpene pool size decreased at elevated CO2, increased at elevated temperature and did not change in response to nitrogen fertilization. Overall, we did not find that foliar nitrogen, carbon balance, or rate of monoterpene synthesis alone were consistent predictors

of monoterpene concentration in current-year Douglas fir needles. In addition, despite a wound-induced decrease in monoterpene pool size, we found no evidence for induction of monoterpene synthesis in response to wounding. The influence of either resource availability or wounding on rates of monoterpene synthesis or accumulation cannot be explained by traditional supply-side or demand-side controls. We conclude that monoterpene synthesis in first-year Douglas fir needles is controlled by fairly conservative genetic mechanisms and is influenced more by past selection than by current resource state.

OSU Link
Non-OSU Link

78. Lu, S., K.G. Mattson, J.B. Zaerr and J.D. Marshall. 1998. Root respiration of Douglas-fir seedlings: effects of N concentration. Soil-Biology-and-Biochemistry 30(3): 331-336.

Keywords: nursery operations
nursery fertilization
growth
carbon allocation
tree morphology
tree physiology
mycorrhizal response

Abstract: Six-month-old Douglas-fir (Pseudotsuga menziesii) seedlings were grown at three N concentrations and with controlled root temperatures in Oregon, USA. Measurements of root respiration were conducted on undisturbed root systems by passing humidified air with 1000 micro l/litre CO2 through root boxes onto an infrared gas analyser. The effects of N on soil respiration were sought by examining total root respiration rate per seedling, specific root respiration rate/g root dry wt, and root dry wt after N fertilization. Total respiration rates of seedlings grown at 50 mg N/litre concentration were significantly higher than those grown at 10 or 200 mg N/litre. Seedlings grown at N concentration of 200 mg/litre had significantly smaller roots than those grown at the two lower N concentrations. The specific respiration rate increased as N concentration was increased from 10 to 50 mg N/litre, but remained constant as N was further increased from 50 to 200 mg/litre. The increase of total respiration rate with the increase in N concentration from 10 to 50 mg/litre was attributed to the increase in specific respiration, whereas the subsequent decrease in total respiration with the increase in N concentration from 50 to 200 mg/litre was attributed to the decrease in root dry wt. The depression of soil respiration after the addition of N fertilizers to relatively fertile soil may be explained by reduced root and mycorrhizal mycelial growth.

OSU Link
Non-OSU Link

79. MacDonald, J.E. 1996. Early development of bud dormancy in conifer seedlings. *In* Plant dormancy: physiology, biochemistry and molecular biology. *Ed.* G.A. Lang. Wallingford, UK: CAB INTERNATIONAL. pp. 193-199.

Keywords: nursery operations
tree phenology

Abstract: A study is reported on 1-yr-old coastal Douglas fir (Pseudotsuga menziesii var. menziesii) nursery seedlings on Vancouver Island, British Columbia, with the aim of determining whether there was a difference in dormancy development in response to short-day or moderate moisture stress treatments. Successful dormancy induction was obtained during the first week of both types of treatment, but the phenology of dormancy development was different, being earlier in the short-day treatment. Of the short-day treatments tested (3-6 wk), dormancy development was earliest for the 4-wk duration.

OSU Link
Non-OSU Link

80. Malavasi, M.d.-M., S.G. Stafford and D.P. Lavender. 1985. Stratifying, partially redrying and storing Douglas-fir seeds: effects on growth and physiology during germination. Annales-des-Sciences-Forestieres 42(4): 371-383.

Keywords: nursery operations
reproduction
growth

Abstract: Douglas fir seeds collected from one coastal and one inland source in Oregon, USA, were stratified at 3 degrees C for 28 days at 45% m.c., and then redried to 35% or 25% m.c. and/or stored at 3 degrees C for 1 or 3 months. Redrying stratified seeds to 35% m.c. did not affect the m.c. of embryos or gametophytes, but redrying to 25% m.c. reduced the m.c. of all seed structures. Three months storage did not alter moisture distribution within seeds. Stratification reduced the germination % of seeds from the inland source, but hastened germination speed of seeds from both sources. Redrying stratified seeds to 35% and 25% m.c. increased seed vigour and seedling length and dry weight. Storing stratified seeds without redrying them generally reduced seed vigour. These results suggest that it would be advantageous to redry seeds to a range of 25-35% m.c. directly before sowing in order to produce vigorous seedlings or allow expression of stratification benefits.

OSU Link
Non-OSU Link

81. Margolis, H.A. and R.H. Waring. 1986a. Carbon and nitrogen allocation patterns of Douglas-fir seedlings fertilized with nitrogen in autumn. I. Overwinter metabolism. Canadian-Journal-of-Forest-Research 16(5): 897-902.

Keywords: nursery operations
nursery fertilization
tree physiology

Abstract: Dormant Douglas fir seedlings (2+0) in a western Oregon nursery were fertilized with ammonium nitrate in Oct. 1983 and harvested for biochemical analyses before fertilization and in Nov. 1983 and Feb. and Mar. 1984. Free amino acid (FAA) concn. and total N in the needles of fertilized seedlings showed a large increase 1 month after fertilization. FAA concn. of fertilized seedlings decreased in needles during winter, but remained stable in stems and fine roots. Just before budbreak in mid-Mar., FAA concn. increased significantly in needles and stems. Total N increased 1 month after

fertilization, remained stable during winter and tended to decrease just before budbreak. Starch and total nonstructural carbohydrate concn. of needles and stems were lower in fertilized than in unfertilized seedlings just before budbreak. When data from all harvests were combined, sugar concn. of fine roots were lower in fertilized seedlings. The depletion of carbohydrate reserves following N fertilization probably reflected increased maintenance respiration which required synthesis of additional enzymes.

OSU Link
Non-OSU Link

82. Margolis, H.A. and R.H. Waring. 1986b. Carbon and nitrogen allocation patterns of Douglas-fir seedlings fertilized with nitrogen in autumn. II. Field performance. Canadian-Journal-of-Forest-Research 16(5): 903-909.

Keywords: nursery operations
nursery fertilization
tree phenology
growth
tree physiology

Abstract: Douglas fir seedlings (2+0), unfertilized or fertilized with ammonium nitrate in Oct. 1983, were planted out in Feb. 1984 near Corvallis, Oregon. Rye grass was grown on half the plots to induce water stress during the typical summer drought. Sucrose was applied to soil around each seedling to stimulate microbial growth and thus to immobilize nitrogen in the microbial biomass and create nitrogen stress in Douglas fir. Fertilized seedlings had earlier budbreak, produced more shoot growth and had higher relative growth rates, net assimilation rates and leaf area ratios than unfertilized seedlings. Grass significantly increased predawn moisture stress in both fertilized and unfertilized seedlings by early Aug. By 3 Sep., unfertilized seedlings growing with grass were significantly more stressed than other seedlings. Fertilizer did not have a significant effect on concn. of free amino acids and total N at the end of the growing season, but grass competition affected both N and carbohydrate chemistry.

OSU Link
Non-OSU Link

83. McClain, K.M. and D.P. Lavender. 1988. Tissue water relations and survival of conditioned conifer seedlings during drought stress. *In* Proceedings: 10th North American Forest Biology Workshop, 'Physiology and genetics of reforestation', University of British Columbia, Vancouver, British Columbia, July 10-22, 1988. Eds. J. Worrall, J. Loo-Dinkins and D.P. Lester. pp. 177-185.

Keywords: nursery operations
tree/stand protection
tree physiology
tree/stand health

Abstract: Jack pine (Pinus banksiana) and Douglas fir (Pseudotsuga menziesii) 23-week-old seedlings were subjected to an 8-week drought stress period on two soil types (sandy clay loam and loamy sand) in protected cold frames in a nursery in Oregon in July-August 1984. Before transplanting, treatments

consisting of daily or weekly irrigations, combined with 0 or 100 p.p.m. KCl, were applied to the seedlings for 6 weeks. The results showed that weekly irrigated (stress conditioned) seedlings maintained higher water potentials than daily irrigated (non-stress conditioned) seedlings. Decreases in water potential were more rapid for seedlings grown on sand than for seedlings grown on loam. By the end of the assessment period, relative water contents of Douglas fir on sand and loam were 88.3% and 91.5%, respectively, and 72.7% and 81.8%, respectively, for jack pine. Turgor pressures were maintained at higher levels in Douglas fir than in jack pine on both soil types. On sand, mortality in both species was dependent on conditioning treatment, indicating that stress conditioning enhanced seedling drought resistance during a period of rapidly increasing soil water deficit. KCl treatment was not implicated in response to drought, but increased mortality of jack pine on sandy clay loam.

Non-OSU Link

84. McCreary, D.D., D.P. Lavender and R.K. Hermann. 1990. Predicted global warming and Douglas-fir chilling requirements. Annales-des-Sciences-Forestieres 47(4): 325-330.

Keywords: genetic tree improvement
nursery operations
tree phenology
growth

Abstract: Containerized Douglas fir (Pseudotsuga menziesii) seedlings from warm coastal and cool mountainous Oregon seed sources, grown under natural conditions, were chilled at constant temperatures of 5, 7 or 9 degrees C for 9, 11, 13 or 15 weeks beginning in mid-October. After a growth period of 9 weeks following chilling, degree of budbreak and dry weight of new shoot growth were measured. The longest and coldest chilling treatment produced the greatest growth response for all seed sources. Results are discussed with reference to predicted global warming, in particular the potential difficulty of reducing Douglas fir chilling requirements through tree breeding programmes.

OSU Link
Non-OSU Link

85. McKay, H.M. 1994. Frost hardiness and cold-storage tolerance of the root system of Picea sitchensis, Pseudotsuga menziesii, Larix kaempferi and Pinus sylvestris bare-root seedlings. Scandinavian-Journal-of-Forest-Research 9(3): 203-213.

Keywords: nursery operations
tree/stand protection
tree physiology
tree/stand health

Abstract: During the winter of 1990-91, fine roots of 2-year-old, undercut and wrenched Pseudotsuga menziesii, Larix kaempferi [L. leptolepis], Pinus sylvestris, and Picea sitchensis (Alaskan, Queen Charlotte Islands and Oregon provenances) were tested using electrolyte leakage for frost hardiness and tolerance to storage at +1 degrees C for 30 and 90 days as excised roots. Pseudotsuga menziesii and Pinus sylvestris showed only minor changes in root frost hardiness with a maximum of -4 degrees C and -7 degrees C respectively. Larix leptolepis and Picea sitchensis developed much greater root frost

hardiness; L. leptolepis had a maximum hardiness of -12 degrees C while Picea sitchensis (Queen Charlotte Islands) reached -13 degrees C during the winter. The root frost hardiness of Picea sitchensis increased with the provenance's latitude. There were clear species and provenance differences in the level of long-term cold-storage tolerance attained, increasing in the order Pseudotsuga menziesii, Pinus sylvestris and Picea sitchensis (Oregon), L. leptolepis, Picea sitchensis (Queen Charlotte Islands), and Picea sitchensis (Alaskan). In spite of highly significant correlations between root electrolyte leakage after cold-storage and frosting tests, root frost hardiness did not accurately indicate all aspects of long-term cold tolerance and has limitations as a means of determining safe cold-storage dates.Tr.

OSU Link
Non-OSU Link

86. 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

87. Minore, D., H.G. Weatherly and P.G. Cunningham. 1993. Sowing at 1.5-cm (0.6-inch) depth produces heaviest Douglas-fir roots in small containers. Tree-Planters' Notes 44(3): 122-124.

Keywords: nursery operations
tree morphology
growth
reproduction

Abstract: Sowing seeds of Douglas fir (Pseudotsuga menziesii) at five depths in Leach Super Cells indicated that the only benefit of deep sowing in small containers occurred at a depth of 1.5 cm. Sowing at this depth produced heavier roots without a significant reduction in seedling emergence. Sowing at greater depths significantly reduced seedling emergence and growth.

OSU Link
Non-OSU Link

88. Mohammed, G.H., K.R. Patel and W.E. Vidaver. 1989. The control of adventitious root production in tissue-cultured Douglas-fir. Canadian-Journal-of-Forest-Research 19(10): 1322-1329.

Keywords: nursery operations
reproduction
growth
tree morphology

Abstract: Rooting percentage and root number in tissue-cultured Douglas fir (Pseudotsuga menziesii) were examined to assess the influence of rooting substrate, the concentrations of sucrose and boron in the rooting medium, shoot height, and shoot generation. Peat/perlite was a better substrate than agar, producing 70% compared with 0% rooted shoots, respectively. On peat/perlite, cell divisions were organized and were associated with tracheid nests, whereas on agar proliferation was neither organized nor restricted to the nests. An optimum sucrose concentration of 4% was found for the production of nodular or rooted shoots. At 4% sucrose and 3 mg/litre boric acid, 100% of the shoots rooted, and the mean root number was 11. Rooting percentage and root number were significantly greater with shoots that were 3 cm tall rather than 2 or 1 cm tall. Shoot responses were more rapid in third and fourth generation shoots, with at least 80% rooted or nodular after 4 weeks, compared with only 36% from the second generation.

OSU Link
Non-OSU Link

89. Molina, R. and J. Chamard. 1984. Use of the ectomycorrhizal fungus Laccaria laccata in forestry. II. Effects of fertilizer forms and levels on ectomycorrhizal development and growth of container-grown Douglas-fir and ponderosa pine seedlings. Canadian-Journal-of-Forest-Research 13(1): 89-95.

Keywords: nursery operations
nursery fertilization
mycorrhizal response
growth

Abstract: [See FA 44, 2464] Seedlings were grown in peat/vermiculite medium with or without pre-germination inoculation with L. laccata, using three rates of soluble NPK fertilizer (low, high, and a combination of low changed to high) or full or half strength of a slow-release fertilizer. Ectomycorrhizal development was excellent for both hosts regardless of fertilizer treatment; ectomycorrhizal short roots averaged 93.6% for Douglas fir and 94.5% for ponderosa pine. Inoculation did not affect the size of Douglas fir but significantly reduced growth of ponderosa pine at low fertility.

OSU Link
Non-OSU Link

90. Muller, C., E. Falleri, E. Laroppe and M. Bonnet Masimbert. 1999. Drying and storage of prechilled Douglas fir, Pseudotsuga menziesii, seeds. Canadian Journal of Forest Research 29:172-177.

Keywords: nursery operations
reproduction

Abstract: Douglas fir, Pseudotsuga menziesii, seeds exhibit relative dormancy as they do not germinate at suboptimum temperature (15°C), whereas at optimum temperature (20°C) some germination occurred. Thus, germination at 15°C was chosen to estimate dormancy release. In the first experiment, seeds were prechilled at 32% moisture content (MC) for 0-34 weeks at 3°C. Long chilling treatments enhanced germinability and, more markedly, germination speed both at 20°C and at 15°C. Seeds pretreated for the longest periods were then dried to 6.7% MC and stored up to 6 months without any detrimental effect on germination at 15°C. In the second experiment, seeds from a second seedlot were prechilled for 18 weeks and then stored at three different MCs (6.7, 7.2 and 8.1%) over a period of 17 months. Seeds stored at the lowest MC germinated fastest and to the highest percentage both at 15 and 20°C. In the nursery, seedling emergence tests confirmed results from this experiment.

OSU Link
Non-OSU Link

91. Newton, M., E.C. Cole and D.E. White. 1993. Tall planting stock for enhanced growth and domination of brush in the Douglas-fir region. New-Forests 7(2): 107-121.

Keywords: nursery operations
site preparation
prescribed fire
release treatments
chemical release
growth
tree/stand health

Abstract: Two long-term experiments in Oregon followed the development of planted stock of various sizes, origins, and species. In one experiment, multi-year comparisons of container, 2+0 bare rooted, and 3-yr-old Douglas fir (Pseudotsuga menziesii) transplants showed a strong positive relation between initial height and long-term (10-14 yr) growth under a range of site conditions with high probability of brush development. In another experiment, Douglas fir, western hemlock (Tsuga heterophylla), and Sitka spruce (Picea sitchensis) were planted on brushfield sites (disturbed by logging 0 and 4 yr previously) where salmonberry (Rubus spectabilis) was or had been dominant. Half the seedlings were released with glyphosate 6 months after planting. Western hemlock and Douglas fir bare rooted stock all grew well if planted in a fresh burn, despite rapid regrowth of salmonberry, but virtually all seedlings less than 60 cm tall except Sitka spruce were killed by 4-yr-old salmonberry if not released. Release improved growth of seedlings in the fresh burn by 6%, gaining an average of about 0.6 year toward reaching a height of 6 m. Release improved growth of survivors in 4-yr-old salmonberry by 51% in height, 72% in diameter, and 325% in volume at age 12 yr. Sitka spruce grew well until damaged by

insects. Western hemlock growth was equal to or greater than that of Douglas fir of comparable initial height. In all comparisons, the probability of being overtopped by brush decreased with increasing initial stock height, and the effect of suppression on growth was also inversely related to initial height. Tall wilding seedlings had comparable advantages to nursery-grown seedlings, although Sitka spruce survival was not reliable.

OSU Link
Non-OSU Link

92. Owston, P.W., W.G. Thies and W. Fender. 1986. Field performance of Douglas-fir seedlings after treatment with fungicides. Canadian-Journal-of-Forest-Research 16(6): 1369-1371.

Keywords: nursery operations
tree/stand protection
tree/stand health
growth
mycorrhizal response

Abstract: Douglas fir seedlings grown in containers with pasteurized or unpasteurized potting mixture, and treated in the nursery with benomyl, captan, fenaminosulf or ethazol [etridiazole], or left untreated (control) were planted out in the Cascade Range, western Oregon. The seedlings from all treatments appeared to be in similar condition at the time of planting, except for variations in ht. After 7 yr, seedlings grown in pasteurized potting mixture had better survival than those grown in unpasteurized mixture. Benomyl-treated seedlings in pasteurized potting mixture had significantly better survival than control seedlings in pasteurized mixture and seedlings treated with ethazol and grown in unpasteurized potting mixture had significantly lower survival than control seedlings in unpasteurized mixture. Ht. differences after 7 yr were n.s.d. between treatments. Benomyl, captan and ethazol appeared to have no detrimental effect on the development of mycorrhizas after planting non-mycorrhizal seedlings. There were insufficient seedlings to determine the effects of fenaminosulf on mycorrhizas.

OSU Link
Non-OSU Link

93. Parke, J.L., R.G. Linderman and C.H. Black. 1983a. The role of ectomycorrhizas in drought tolerance of Douglas-fir seedlings. New-Phytologist 95(1): 83-95.

Keywords: nursery operations
tree/stand protection
photosynthesis
tree physiology
mycorrhizal response

Abstract: Pseudotsuga menziesii seedlings were watered daily or conditioned to cyclic drying and re-wetting of the soil. Net photosynthesis rates of mycorrhizal and non-mycorrhizal seedlings watered daily were similar but drought-stressed mycorrhizal seedlings fixed CO2 at a rate 10 times that of non-mycorrhizal ones. Total leaf water potentials of mycorrhizal plants were lower than those of non-mycorrhizal plants but they recovered more rapidly. Non-mycorrhizal seedlings and those inoculated

with 4 ectomycorrhizal fungi were allowed to dry, then re-watered and compared for their ability to tolerate and recover from drought. Those inoculated with Rhizopogon vinicolor were the least affected by drought. Net photosynthetic rate of R.-inoculated seedlings 24 h after re-watering was 7 times greater than that of non-mycorrhizal seedlings. The transpiration rate of R.-inoculated seedlings was low before desiccation, declined rapidly during the drought period and, after re-watering, quickly resumed a rate higher than that for other treatments.

OSU Link
Non-OSU Link

94. Peterson, M. and J.R. Sutherland. 1989. Grey mould control by seedling canopy humidity reduction through under-bench ventilation and styroblock aeration. B.C. Ministry of Forests FRDA-Report 077. 15 p.

Keywords: nursery operations
growth
tree/stand health
tree morphology

Abstract: The potential for grey mould control on Douglas-fir seedlings was investigated using under-bench ventilation and aerated styroblocks. Twenty-five percent of all ventilated styroblock seedlings were infected with Botrytis cinerea while 75% of the control seedlings showed signs of infection. The reduced incidence of grey mould in the ventilated treatments was attributed to a more rapid drying of the seedling canopy following watering. The lowest frequency of ideal conditions for B. cinerea infection by spore germination was observed in the seedling canopy of the treatment receiving unheated, forced air ventilation.

OSU Link
Non-OSU Link

95. Peterson, M.J. and J.R. Sutherland. 1990. Controlling gray mold on container-grown Douglas-fir by modified styroblocks and under-bench, forced air ventilation. Western-Journal-of-Applied-Forestry 5(3): 75-79.

Keywords: nursery operations
tree/stand protection
growth
tree/stand health

Abstract: The control of grey mould (Botrytis cinerea) on Douglas fir (Pseudotsuga menziesii) seedlings was investigated in Vancouver, Canada. Incidence of mould on seedlings sown in June 1988 and assessed January 1989 was reduced in 3 treatments of modified styroblocks (vertical holes, allowing air movement from below): vented with heated, forced air; vented with unheated, forced air; and vented with unheated, unforced air. Overall, mould occurred on 25% of 7-month-old seedlings in vented styroblocks, compared with >75% incidence in unmodified styroblocks. No significant differences in seedling height or root collar diameter among treatments were observed. Use of ventilated styroblocks is recommended, to reduce both losses from grey mould and fungicide usage in nurseries.

OSU Link
Non-OSU Link

96. Peterson, M.J. and S.E. Tuller. 1987. Die-back of container-grown Douglas-fir seedlings: associated microclimate. B.C. Ministry of Forests FRDA-Report 035. vii + 43 p.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: Microclimate associated with needle-tip dieback of Pseudotsuga menziesii seedlings in containers was studied in 2 greenhouses in British Columbia. The effects of 2 kinds of grit cover on soil temperature were also examined.

OSU Link
Non-OSU Link

97. Pilz, D. and R.M. Znerold. 1986. Comparison of survival enhancement techniques for outplanting on a harsh site in the western Oregon Cascades. Tree-Planters' Notes 37(4): 24-28.

Keywords: nursery operations
planting operations
growth
tree/stand health
mycorrhizal response

Abstract: Bare rooted 2+0 seedlings of Pseudotsuga menziesii survived and grew better during the first year than container-grown 1+0 stock on a droughty site. After 3 yr, survival still differed significantly, but height growth did not. Shading improved survival and growth. Application of a liquid suspension of spores of Pisolithus tinctorius was ineffective and no mycorrhizas developed from this fungus.

OSU Link
Non-OSU Link

98. Poulsen, K.M. 1996. Prolonged cold, moist pretreatment of conifer seeds at controlled moisture content. Seed Science and Technology 24:75-87.

Keywords: nursery operations
reproduction
tree/stand health

Abstract: Cold pretreatment of imbibed seed (stratification) and seed kept at controlled moisture contents for 3-14 weeks was tested for commercial seedlots of Abies nordmanniana, Abies procera, Pseudotsuga menziesii and Picea sitchensis in order to give recommendations for nursery practice. The temperature tolerance of treated seed was tested by germinating seed at four temperature regimes. It was possible to pretreat Abies nordmanniana seed at controlled moisture content, but the performance was not improved compared to the traditional six weeks stratification of imbibed seed. For Abies

procera seed pretreatment at controlled moisture content for 2 + 8 weeks (2 weeks imbibed followed by 8 weeks at controlled moisture content) or more, significantly improved the performance at the germination temperatures 15 and 30°C. For Pseudotsuga menziesii seed pretreatment at controlled moisture content for up to 2 + 12 weeks was superior, especially at low germination temperatures, and it was possible to redry pretreated seed to 8% moisture content without loss of the pretreatment effect or germination capacity. For Picea sitchensis seeds the controlled moisture content method for a duration of 7-10 weeks proved efficient and pretreated seed of this species also tolerated redrying. It is recommended that these improved pretreatment methods should be introduced into the nurseries.

OSU Link
Non-OSU Link

99. Puttonen, P. 1987. Abscisic acid concentration in Douglas-fir needles in relation to lifting date, cold storage, and postplanting vigor of seedlings. Canadian-Journal-of-Forest-Research 17(5): 383-387.

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

Abstract: Spring-lifted seedlings (2+0) were grown outside in pots at Corvallis, Oregon, in 1982. In late July pots were watered weekly to induce dormancy. From early Sep., plants received either a natural photoperiod or an extended (16 h) photoperiod for 6 wk. In mid-Nov. 1982 or mid-Jan. 1983, the plants were lifted and stored in a cold room (4 degrees C) for 25 days, bare rooted in polyethylene bags in the dark, or in pots in the dark or with an 8 h photoperiod. After storage, seedlings were planted in a cold frame or in pots in a growth room with 16-h photoperiod and day/night temp. of 21/16 degrees . In Sep. 1983, seedling ht., length of leader for 1982 and 1983, root collar diam. and survival were recorded. ABA concn. in needles was analysed after 48h and 25 days in storage, after 48h in a cold frame or growth room and at bud break. Lifting times and storage treatments did not have a significant effect on ABA concn. Seedling vigour was not indicated by ABA concn. There were treatment differences in performance after storage. Compared with seedlings lifted in mid-Jan., those lifted in mid-Nov. had reduced survival and more days to bud burst.

OSU Link
Non-OSU Link

100. Radwan, M.A. 1992. Effect of forest floor on growth and nutrition of Douglas-fir and western hemlock seedlings with and without fertilizer. Canadian-Journal-of-Forest-Research 22(9): 1222-1229.

Keywords: nursery operations
nursery fertilization
growth
tree physiology

Abstract: Experiments were conducted to determine the effects of four different forest soils from western Washington, USA, on growth and shoot nutrients of potted Douglas fir (Pseudotsuga menziesii)

and western hemlock (Tsuga heterophylla) seedlings, in the absence and presence of forest floor, and with and without N and P fertilizers. Nine-month-old seedlings from low-altitude seed sources were used, and seedlings were grown for 2 years in a roofed lathhouse. Soils were of the Klone, Vesta, Bunker, and Shelton series; samples of Klone and Vesta soils, and of Bunker and Shelton soils (to 20 cm depth), were collected from western hemlock and Douglas fir stands, respectively. Forest floor samples were collected from the same sites. Fertilizer was added as ammonium nitrate at 100 kg N/ha and triple superphosphate at 226 kg P/ha. The forest floor, at 70 g/7.6-litre pot, and the N and P fertilizers were added to the top of the planting pots without mixing. The P, N, K, Ca and Mg contents of the forest floor, mineral soils and shoots were measured. The forest floors and mineral soils differed by source in many of the chemical characteristics determined. Overall, seedling growth of Douglas fir and western hemlock was better in the Klone and Shelton soils than in the Bunker and Vesta soils. Seedlings, especially those of western hemlock, grew better in soils with forest floor than without forest floor. The N fertilizer reduced seedling growth of both species and, in some soils, reductions were more in soils with forest floor. The P fertilizer improved seedling growth of both species in all soils, and with one exception, growth was much greater in the presence than in the absence of the forest floor. With both species, soil, forest-floor, and fertilizer treatments affected concentrations and contents of the various shoot nutrients determined. The nutritional changes observed varied by nutrient and reflected differences in uptake of native and fertilizer nutrients, as well as changes in shoot dry weight. The results demonstrate the importance of the forest floor to growth and nutrition of Douglas fir and western hemlock seedlings, especially when fertilizers are used.

OSU Link
Non-OSU Link

101. 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

102. Randall, W. and G.R. Johnson. 1998. The impact of environment and nursery on survival and early growth of Douglas-fir, noble fir, and white pine - a case study. Western-Journal-of-Applied-Forestry 13(4): 137-143.

Keywords: nursery operations
planting operations
tree/stand protection
growth
tree/stand health

Abstract: Survival and third-year height were examined on 2383 reforestation units in Cascade Range of western Oregon, USA, from 1983 to 1994, to determine which factors affect reforestation success. The three species examined made up 92% of the total trees planted in the region. Survival of Douglas fir (Pseudotsuga menziesii) varied by as much as 20% from year to year. The most significant factor affecting reforestation success was the nursery that provided the seedlings. Nursery affected both survival and height of Douglas fir and height for noble fir (Abies procera) and white pine (Pinus monticola). No nursery was best for all species. Other factors that were important for all three species were the administrative unit where the seedlings were planted, initial plant height, aspect, and length of storage prior to planting. Other significant factors that were important for Douglas fir were seed origin, planting month, protection, stock type, and aspect. For noble fir, other important factors were planting month and stock type; for white pine, the other important factor was slope. Altitude of the seed source and the planting unit affected Douglas fir survival and height but did not affect the other two species. This supports the smaller altitudinal bands for Douglas fir compared with noble fir and white pine.

OSU Link
Non-OSU Link

103. Ritchie, G.A. 1984. Effect of freezer storage on bud dormancy release in Douglas-fir seedlings. Canadian-Journal-of-Forest-Research 14(2): 186-190.

Keywords: nursery operations
tree phenology
tree/stand health

Abstract: Two-yr-old seedlings from 4 western Washington and Oregon provenances were lifted from the nursery on Dec. 11, 1979 and Jan. 21, Feb. 13 and March 11, 1980, following the accumulation of about 600, 1170, 1550, and 1800 chilling hours (temp. less than 5 degrees C), respectively. They were tested for bud dormancy intensity and vigour immediately after lifting and following 2 and 6 months in freezer (-1 degrees C) storage. Dormancy weakened exponentially with accumulated nursery chilling, with seedlings from all 4 provenances responding similarly. The rate of dormancy release was

substantially retarded by freezer storage, so that by late March stored seedlings were more dormant than those remaining in the nursery beds. Dormancy weakened in storage more rapidly in high-altitude provenances than in provenances from lower altitudes. Early-lifted seedlings lost dormancy more rapidly in storage than did late-lifted seedlings. Vigour following a 6-wk greenhouse trial was good or excellent in all but the Dec.-lifted unstored seedlings and the March-lifted unstored and 6-month stored seedlings.

OSU Link
Non-OSU Link

104. Ritchie, G.A. 1986. Relationships among bud dormancy status, cold hardiness, and stress resistance in 2+0 Douglas-fir. New-Forests 1(1): 29-42.

Keywords: nursery operations
tree/stand protection
growth
tree/stand health
tree phenology
carbon allocation

Abstract: Seedlings were lifted from a western Washington nursery on six dates spanning the 1980-81 lifting season. On each date samples of seedlings were subjected to the following treatment: tumbling for 5 min, desiccation of roots for 30 min at 30 degrees C and 2.1 kPa vapour deficit, exposure of shoots to temp. of -10 degrees C, -15 degrees C or -20 degrees C for 2 h, and unstressed control. On two lift dates sub-samples of seedlings were placed into -1 degrees C storage and held for 2 months before the above treatments were administered. Bud dormancy status was determined, using a bud break test, on seedlings from each lift date before and after storage. After one growing season in the field, percent survival, vigour, height growth and shoot and root weight were determined on stressed and unstressed seedlings. Survival and vigour were less affected by treatments than were height and weight. Severity of stress was in the order -20 degrees C>-15 degrees C>desiccation> handling>-10 degrees C. Degree of cold injury was directly related to seedling dormancy status whether dormancy status had been attained in the nursery from natural chilling or in frozen storage. Seedlings in a mid-range of dormancy release (between deep rest and quiescence) were most resistant to all imposed stresses.

OSU Link
Non-OSU Link

105. Ritchie, G.A., J.W. Keeley and P.A. Ward. 1997. Effects of shade and root confinement on the expression of plagiotropic growth in juvenile-origin Douglas-fir rooted cuttings. Canadian-Journal-of-Forest-Research 27(7): 1142-1145.

Keywords: nursery operations
growth
tree morphology

Abstract: The purpose of this experiment was to determine why juvenile-origin Douglas fir (Pseudotsuga menziesii) rooted cuttings, which remain plagiotropic (branch-like) when grown in containers in shaded

greenhouses, become orthotropic (vertical) after they are transplanted to an outdoor environment. Plagiotropic rooted cuttings (mean angle from vertical = 45-50 degrees) from three full-sib families were transplanted into an outdoor nursery in Olympia, Washington, and subjected to four treatments consisting of a factorial of (1) shaded or unshaded and (2) bareroot or confined roots. After two growing seasons, treatments had significantly affected plant size and biomass in the order unshaded-bareroot > shaded-bareroot > unshaded-confined > shaded-confined, but plants in all treatments had become nearly orthotropic. It is concluded that neither shading nor root confinement is, but other greenhouse environmental conditions are, responsible for the persistence of plagiotropic growth.

OSU Link
Non-OSU Link

106. Ritchie, G.A., Y. Tanaka and S.D. Duke. 1992. Physiology and morphology of Douglas-fir rooted cuttings compared to seedlings and transplants. Tree-Physiology 10(2): 179-194.

Keywords: nursery operations
tree phenology
tree physiology
growth
tree morphology
carbon allocation

Abstract: Cuttings of Douglas fir (Pseudotsuga menziesii) from three open-pollinated families were rooted in two types of tray and then grown for 1.5 years in a nursery in Washington State. During their second winter they were sampled periodically and tested for cold hardiness, dormancy status, root growth potential and various morphological characteristics. Two-year-old seedlings and transplants were tested concurrently for comparison. Rooted cuttings, seedlings and transplants cold hardened at similar rates during early winter, achieving the same level of midwinter hardiness (LT50 = -18 degrees C) in early January. However, rooted cuttings remained hardier later into spring than did seedlings or transplants. Rooted cuttings exhibited deeper dormancy in early winter than seedlings or transplants but these differences disappeared after January. Root growth potentials of all three stock types remained above threshold values established for transplants throughout winter. Rooted cuttings had greater stem diameter, higher stem diameter : height ratio, and greater root weight than either seedlings or transplants. This may reflect lower growing densities for rooted cuttings. Root : shoot ratios of rooted cuttings were greater than for seedlings and similar to those of transplants. Rooted cuttings also had deeper and coarser root systems, which probably reflected lack of wrenching at the nursery.

OSU Link
Non-OSU Link

107. Ritchie, G.A., Y. Tanaka, R. Meade and S.D. Duke. 1993. Field survival and early height growth of Douglas-fir rooted cuttings: relationship to stem diameter and root system quality. Forest-Ecology-and-Management 60(3-4): 237-256.

Keywords: nursery operations
tree/stand health
growth

Abstract: In 1990, three studies involving 11 half-sib families of Douglas fir (Pseudotsuga menziesii) rooted cuttings were established at three sites in western Washington State (two with low regeneration difficulty (RD) and one with high RD). One of the studies, a grading study, compared performance of nine classes of rooted cuttings based on stem diameter and root system quality. A second, cull, study evaluated five different types of putative culls. A third study determined the correlation between number of initial roots and field performance. In the grading study, survival and height growth reflected stem diameter and relative root quality on all three sites. Mean survival by treatment was in the range 92-100%, 82-97% and 66-87% for good, fair and poor relative root quality, respectively. First year height growth varied from approximately 10 cm to 20 cm and was greatest on low RD sites. Second year height growth was from 3 to 4x greater than first year height growth on low RD sites and 2 to 3x greater on the high RD site. Performance of seedlings and transplants was nearly identical to that of rooted cuttings of corresponding stem diameter and root system quality. In the cull study, only trees with stem diameter <less or =>4 mm were deemed true culls owing to significantly reduced survival and height growth. In the root number study, rooted cuttings generally increased in size in the nursery in proportion to root number. However, after 2 years in the field, root number was a very poor predictor of survival and height growth. Results are discussed in the context of the development of culling standards for rooted cuttings of Douglas fir nursery stock, and the use of root morphology as an indicator of stock plant quality and potential.

OSU Link
Non-OSU Link

108. 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

109. Rose, R., J.F. Gleason and M. Atkinson. 1993. Morphological and water-stress characteristics of three Douglas-fir stocktypes in relation to seedling performance under different soil moisture conditions. New-Forests 7(1): 1-17.

Keywords: nursery operations
tree phenology
tree physiology
growth
tree morphology

Abstract: Phenology, morphology, frost hardiness and response to moisture stress were examined for three Douglas fir (Pseudotsuga menziesii) stocktypes grown from the same seed lot in a nursery near Olympia, Washington, USA. The types were mini-plugReg. transplants (MPT), 1+1 bareroot transplants (1+1), and 2+0 bareroot seedlings (2+0). In the late summer and autumn before lifting, 2+0 seedlings set bud before 1+1 seedlings and 1+1 seedlings before MPT seedlings. The 2+0 seedlings appeared slowest to acquire frost hardiness and seemed to deharden most rapidly in spring. Although 2+0 seedlings were taller than the MPT stocktype, MPT and 2+0 seedlings were relatively similar in other morphological respects, but 1+1 seedlings were much larger. All stocktypes were potted on 20 January 1989, placed in a greenhouse, and subjected to 39%, 18%, 16%, or 6% soil water-content (% dry weight) until the end of the experiment in mid-July 1990. The largest decrease in pre-dawn xylem water potential occurred with 16% and 6% soil water content; pre-dawn xylem water potential averaged over the three stocktypes generally declined 219% from low to high soil moisture stress. The 1+1 seedlings used more water than the other two stocktypes, and at maximum soil moisture stress, plant moisture stress increased in the order MPT < 2+0 < 1+1. During the 6-month greenhouse experiment, the larger 1+1 stocktype showed the most absolute growth, but the smaller stocktypes grew more on a relative scale. Growth of the stocktypes appeared to be related to differences in morphology and water-use patterns as the seedlings competed for available water within each pot. The results show that MPT seedlings, a new stocktype, performed as well as the more traditionally used 2+0 and 1+1 seedlings and that stocktype selection is important in reforestation efforts.

OSU Link
Non-OSU Link

110. Rose, R. and D.L. Haase. 1995. Effect of the antidesiccant Moisturin on conifer seedling field performance. Tree-Planters' Notes 46(3): 97-101.

Keywords: nursery operations
growth
tree/stand health

Abstract: Two concentrations of the antidesiccant Moisturin were applied to Douglas fir (Pseudotsuga menziesii) and ponderosa pine (Pinus ponderosa) seedlings after lifting by either dipping or spraying. Seedlings were outplanted to 5 typically dry sites in Oregon and to a garden plot at Oregon State University. Seedling performance was assessed at the end of the first growing season. Despite trends in plant moisture stress measurements that suggest reduced transpirational loss, there were no significant treatment effects on height growth, survival, or stem diameter growth at any of the study sites nor in the garden plot.

OSU Link
Non-OSU Link

111. Rose, R. and D.L. Haase. 2000. The use of coir as a containerized growing medium for Douglas-fir seedlings. Native-Plants-Journal 1(2): 107-111.

Keywords: nursery operations
growth
carbon allocation
tree physiology
tree morphology
soil properties

Abstract: In response to environmental concerns and the need for peatland conservation, alternative growing media for conifer seedling production must be investigated. Douglas-fir (Pseudotsuga menziesii) seedlings were grown in 6 media; components included peat moss, peat moss amended with sawdust, and 2 sources of coir (coconut fibre) mixed with and without peat moss. Coir had higher pH, P, K, and Na and lower Ca and N than peat moss and a peat moss-sawdust mixture. Bulk densities of coir and coir-based media were lower than those in peat moss and a peat moss-sawdust mixture. After 21 weeks, seedlings grown in coir-based media were significantly smaller and had lower foliar N and Ca than those grown in peat moss. Because of coir' many favourable qualities, further research is recommended using culturing regimes specific to the substrate's nutrient properties.

OSU Link
Non-OSU Link

112. Rose, R., D.L. Haase, F. Kroiher and T. Sabin. 1997. Root volume and growth of ponderosa pine and Douglas-fir seedlings: a summary of eight growing seasons. Western-Journal-of-Applied-Forestry 12(3): 69-73.

Keywords: nursery operations
growth
tree/stand health

Abstract: Survival, growth, and stem volume were determined for 2+0 bare-root ponderosa pine (Pinus ponderosa) and Douglas fir (Pseudotsuga menziesii) seedlings, 8 growing seasons after planting in 1987 on sites near, respectively, Wamic or Vernonia, Oregon. For each species, seedlings from three seedlots were assigned to one of three root-volume categories (<4.5, 4.5-7 and >7 cmsuperscript 3 for ponderosa pine; <9, 9-13 and >13 cmsuperscript 3 for Douglas fir). On a dry harsh ponderosa pine site on the eastern slopes of Mt. Hood, where gopher [Thomomys sp.] and cattle damage decreased the number of seedlings, more seedlings in the highest root-volume category survived (70%) than in the smaller root-volume categories (62% and 50%). Douglas fir on a good site in the Coast Rangeshowed significantly greater height and stem volume for the largest root-volume category, whereas annual shoot growth and survival did not differ. Root volume is one of several potentially useful criteria for predicting long-term growth and survival after outplanting.

OSU Link
Non-OSU Link

113. 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

114. Scagel, C.F., R.G. Linderman and R.K. Scagel. 2000. Ten-year growth and survival of Douglas-fir seedlings treated with plant growth regulating substances at transplant. Canadian-Journal-of-Forest-Research 30(11): 1778-1787.

Keywords: nursery operations
growth
tree/stand health
tree morphology

Abstract: Commercially available plant growth regulators (PGRs) or moisture retention gels, applied to the roots of Douglas fir (Pseudotsuga menziesii) before planting, can modify IAA levels in roots, root growth responses, and tree survival. Two different 1+0 stock types (PSB313B and PSB323, interior and coastal Douglas fir, respectively, the latter having a larger root mass) were treated with IBA, ethephon (Ethrel), alginate, or a combination of IBA and alginate. New root growth and IAA levels in roots were measured 2 weeks after planting, and aboveground growth and tree survival were monitored over 10 growing seasons after planting in May 1988 on a site clear felled in winter 1988 in British Columbia, Canada; no site preparation was carried out. Treatment with IBA or the combination of IBA and alginate increased IAA conjugate and free IAA levels in roots, root growth, and tree survival. Alginate treatment alone increased new root growth and tree survival, but did not increase free IAA levels in roots. Ethephon treatment increased free IAA levels and root growth, but had no effect on IAA conjugates or tree survival. A cost analysis suggested that use of certain PGRs or alginate decreased the cost required

to attain target stocking and increased tree size. The results suggest that application of PGRs or other root-promoting materials to the roots of Douglas fir before planting has the potential to be a cost-beneficial method for increasing root growth and tree survival.

OSU Link
Non-OSU Link

115. Schowalter, T.D. 1987. Abundance and distribution of Lygus hesperus (Heteroptera: Miridae) in two conifer nurseries in western Oregon. Environmental-Entomology 16(3): 687-690.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: Seasonal patterns of abundance and distribution of Lygus hesperus were observed at 2 conifer nurseries in western Oregon during 1985. Abundance differed significantly among conifer seedling types (age class-species combinations) and sampling dates. Highest densities were observed in lodgepole pine (Pinus contorta) and ponderosa pine (P. ponderosa) seedlings germinated during 1985, in Douglas fir (Pseudotsuga menziesii) seedlings germinated in 1984 and in late July samples. Significant interaction between seedling type and sample date reflected a shift in L. hesperus occurrence among seedling types during the growing season, especially from 1984 Douglas fir seedlings early in the season to 1985 seedlings later in the season. This shift coincided with the dispersal of the first L. hesperus generation and with pruning of the 1984 seedlings for height control. The results indicate that L. hesperus abundance and distribution in conifer nurseries result from L. hesperus phenology in combination with seasonal changes in the spatial pattern of available resources. The implications for nursery management are discussed.

OSU Link
Non-OSU Link

116. Schowalter, T.D. 1988. Tree breeding and insects: effect of insects on the genetic diversity of Douglas-fir. Northwest-Environmental-Journal 4(2): 346-347.

Keywords: seed orchard management
nursery operations
tree/stand protection
tree/stand health
reproduction
genetic relationships

Abstract: Two studies on the effects of insects on Douglas fir [Pseudotsuga menziesii] seed and seedling production in Oregon are summarized. In the first study, seed losses due to Douglas fir cone gall midge [Cecidomyiidae] and Douglas fir seed chalcid [Megastigmus spermotrophus] were studied. It is suggested that resistance to these pests may be a heritable trait and that tree position within a stand can modify genetically-controlled susceptibility to insect attack. The second study indicated that genetically-controlled susceptibility of seedlings to attack by lygus bug [Lygus sp.] could be modified by their proximity to alternative food plants.

OSU Link
Non-OSU Link

117. Schowalter, T.D. and J.D. Stein. 1987. Influence of Douglas-fir seedling provenance and proximity to insect population sources on susceptibility to Lygus hesperus (Heteroptera: Miridae) in a forest nursery in western Oregon. Environmental-Entomology 16(4): 984-986.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: The effect of Lygus hesperus feeding on seedlings of Douglas fir (Pseudotsuga menziesii) was measured in seedlings representing 2 elevation zones, for each of 2 seed zones, and each of 2 seedling age classes in a forest nursery in Oregon during 1984. Damage frequency and height reduction both indicated significant effects of seed source. Examination of seedling distance from the nursery's west boundary with a lucerne field (a major source of L. hesperus in the nursery) indicated a significant effect of proximity to alternative hosts. These results suggest that seedling susceptibility to damage by L. hesperus is a function of seedling condition and location within the vegetation matrix.

OSU Link
Non-OSU Link

118. Schuch, U.K., M.L. Duryea and L.H. Fuchigami. 1989. Dehardening and budburst of Douglas-fir seedlings raised in three Pacific Northwest nurseries. Canadian-Journal-of-Forest-Research 19(2): 198-203.

Keywords: nursery operations
tree phenology
tree physiology

Abstract: Two-yr-old Douglas fir (Pseudotsuga menziesii) seedlings from 2 seed sources raised in 3 nurseries in Oregon and Washington were tested to see how nursery location affected dehardening (the seasonal transition from a frost-resistant to a frost-susceptible condition) and budburst between Jan. and Mar. 1986. The seedlings were measured with a whole-plant freezing test. In general, seedlings raised at the nursery at the highest alt., and in a few cases trees from the most northerly nursery, were more frost resistant than trees from a coastal nursery. From Jan. to Mar., seedlings from the highest (975 m) seed source had less hardy stem tissue than seedlings from the coastal source (450 m). A growth-chamber experiment confirmed the outdoor dehardening studies. A constant temp. of + 5 degrees C with a 16-h photoperiod maintained cold hardiness, whereas +10 and 15 degrees C with a 16-h photoperiod promoted rapid dehardening after 20 d. The nursery environment influenced budburst; trees raised in the coastal nursery burst bud significantly earlier than trees from the other 2 nurseries. Trees of different provenances from the same nursery burst terminal buds only 2 d apart.

OSU Link
Non-OSU Link

119. Simpson, D.G. 1984. Filmforming antitranspirants: their effects on root growth capacity, storability, moisture stress avoidance, and field performance of containerized conifer seedlings. Forestry-Chronicle 60(6): 335-339.

Keywords: nursery operations
tree physiology
growth
tree/stand health

Abstract: One of 6 antitranspirants was sprayed on Pinus contorta, Picea glauca, Tsuga heterophylla and Pseudotsuga menziesii seedlings before or after a 12-wk storage period at 2 degrees C. Root growth capacity and pre-dawn water potential were measured immediately after treatment or after storage. Sample seedlings were planted out in British Columbia in April and May 1981 and survival and growth recorded after one season (Sept.). XEF-4-3561-A, Wilt Pruf, Folicote and Vapor Gard increased moisture stress avoidance (water potential) in all species. Plantgard and Clear Spray increased it only in T. heterophylla. Root growth capacity was reduced by Folicote and Vapor Gard in Pinus contorta, and by XEF, Wilt Pruf and Vapor Gard in Pseudotsuga menziesii. Growth in the first season was reduced by XEF and Wilt Pruf in P. menziesii, T. heterophylla and Picea glauca, and by Vapor Gard in T. heterophylla and Pseudotsuga menziesii. Growth in Pinus contorta was significantly increased by Wilt Pruf and unaffected by the others. Further trials of Wilt Pruf and XEF on Pinus contorta are recommended.

OSU Link
Non-OSU Link

120. Simpson, D.G. 1990. Frost hardiness, root growth capacity, and field performance relationships in interior spruce, lodgepole pine, Douglas-fir, and western hemlock seedlings. Canadian-Journal-of-Forest-Research 20(5): 566-572.

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

Abstract: Interior spruce (Picea glauca-P. engelmannii complex), lodgepole pine (Pinus contorta), interior and coastal Douglas fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) were grown from seed for 20 wk in containers in a greenhouse, with 18-h photoperiods. Seedlings were then acclimatized under natural daylength and temperature conditions at Vernon, British Columbia, for up to 12 wk (7 September-1 December). To create planting stock batches of varying quality, at 2-wk intervals during the acclimatization period separate samples of seedlings were taken (1) for immediate measurement of foliage frost hardiness or (2) for overwinter storage at 2 degrees C (western hemlock and coastal Douglas fir) or -2 degrees C (interior spruce, lodgepole pine and coastal Douglas fir). After storage, samples were used either for root growth capacity (RGC) measurement or for outplanting at various forest sites in British Columbia. In all species, frost hardiness and RGC increased with increasing weeks of acclimatization. Frost hardiness and RGC were correlated with each other in western hemlock, lodgepole pine and Douglas fir, and with field performance (survival or growth) in interior spruce, lodgepole pine and Douglas fir.

OSU Link
Non-OSU Link

121. Sorensen, F.C. 1996. Effects of length of seed chilling period and sowing date on family performance and genetic variances of Douglas-fir seedlings in the nursery. New-Forests 12(3): 187-202.

Keywords: nursery operations
tree phenology
growth
tree/stand health

Abstract: Seeds of four full-sibling Douglas fir (Pseudotsuga menziesii) families (F) - randomly chosen from about 30 control-pollinated crosses in a second-growth stand in the central Oregon Cascade Range (USA) - were moist chilled (C) for 14, 33, and 77 days and sown (S) 29 March, 26 April, and 24 May at two densities (D = 111 and 200 seeds/msuperscript 2), grown for 2 years in nursery beds and phenology and size traits recorded. The study was analysed in two parts: part I evaluated seed treatment effects and their interactions with families; and part II investigated the effect of treatments on genetic variances, particularly among-family (sigma superscript 2F) and within-plot (sigma superscript 2w) components and the intraclass correlation for families (tf). In part I there were large and highly significant differences associated with C and S and among F for all traits. Early S combined with long C resulted in early emergence and gave large seedlings with little loss and damage. Many interactions between C and F, and S and F, were significant. Interactions involved rank changes for size but not for phenology traits, and were larger for CxF than for SxF. Seedling density affected seedling size but not phenology, did not interact with seed treatments, and interacted significantly but weakly with families. In part II, C and S, but not D, had significant effects on sigma superscript 2F, sigma superscript 2w, and tf, but not in a predictable manner. Because of significant interactions, it is recommended that standardized seed treatments be used in family nursery tests. This should help to keep the results from these tests as repeatable as possible. Long chilling and sowing as early as practicable are recommended to minimize disease losses and winter damages and to provide good nursery stock.

OSU Link
Non-OSU Link

122. Sorensen, F.C. 1997. Effects of sib mating and wind pollination on nursery seedling size, growth components, and phenology of Douglas-fir seed-orchard progenies. Canadian-Journal-of-Forest-Research 27(4): 557-566.

Keywords: genetic tree improvement
nursery operations
growth
tree/stand health
tree morphology
tree phenology

Abstract: Polymix outcross (X), full-sib (FS), and wind-pollination (WP) families were produced on 25 seed trees and 10 half-sib families on 10 of the same trees in a Pseudotsuga menziesii var. menziesii seedling seed orchard in Oregon. Seedlings were raised at 2 sowing densities for 2 years in the nursery,

and inbreeding depression (ID) in seedling size related to inbreeding effect on growing season length and growth rate. Seedling mortality was light and not affected by inbreeding. Mean ID for 2-year size traits was 6% (height) and about 8% (diameter) per 10% increase in F, the inbreeding coefficient, and was linear with the increase in F over the range of F used. Both amount of ID and its fit to linearity differed greatly among seed trees. Elongation season was significantly and slightly shorter for FS than for X families; second-year relative elongation rate was nonsignificantly larger for FS than for X families. Inbred families had nonsignificantly larger within-plot variance and significantly larger coefficients of within-plot variance than X families. Sowing density was not a significant factor except in diameter and height/diameter ratio. Results are discussed in terms of plant growth habit and possible gene action. WP compared with X families were significantly shorter by 3.8% and significantly smaller in diameter by 4.6%, with much variation among family groups. About half of the height difference could be explained by seed weight; the remainder could have been due to pollen contamination or natural inbreeding. Progenies of the two pollen types did not differ for phenological traits, even though the seed orchard was in a drier, more inland location than the parent-tree locations. Progenies of WP had nonsignificantly larger within-plot variance than X progenies.

OSU Link
Non-OSU Link

123. Sorensen, F.C. and R.K. Campbell. 1985. Effect of seed weight on height growth of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco var. menziesii) seedlings in a nursery. Canadian-Journal-of-Forest-Research 15(6): 1109-1115.

Keywords: seed orchard management
nursery operations
growth
reproduction

Abstract: Seeds of different mean wt. were produced within each of 10 young Douglas fir trees in a second growth stand in Oregon by leaving some developing cones unbagged and by enclosing others in paper bags for 164 days (from shortly before floral bud flush) or for 117 days (from 26 days after floral buds had been at max. receptivity for pollen). Bagging increased numbers of filled seeds per cone and wt. of individual seeds; 117 days in a bag increased seed wt. by an av. 10.7%. Seed from wind pollinated cones (unbagged or bagged after 26 days receptivity to pollen) were sown in an outdoor nursery at Corvallis, Oregon. Bagging did not affect numbers of cotyledons, but 1st-yr epicotyl length and 2nd-yr total ht. increased by 9.1 and 4.0% respectively. Relations between seed wt. and seedling growth are compared with other reports and inconsistencies are discussed. A growth model was used to project seed wt. differences to later ages and practical implications of long-term effects of seed wt. on plant size, of increasing seed size by cultural techniques and of grading seed lots by size were considered.

OSU Link
Non-OSU Link

124. St-Clair, J.B. and W.T. Adams. 1991a. Effects of seed weight and rate of emergence on early growth of open-pollinated Douglas-fir families. Forest-Science 37(4): 987-997.

Keywords: genetic tree improvement

nursery operations
reproduction
genetic relationships
growth

Abstract: Open-pollinated seeds were collected from 39 Douglas fir (Pseudotsuga menziesii var. menziesii) families in second-growth stands in the Coast Range of west-central Oregon (150-500 m altitude) in autumn 1985. Seed weight, time of emergence, and three measures of seedling size were recorded for each family in order to assess family variation in seed weight and emergence, and the influence of these seed traits on early growth. Seeds were dewinged, cleaned and stored at 0 degrees C. In April 1986, seeds and germinants were sown at a depth of 8 mm to test whether using germinants minimized seed effects on early growth. To evaluate the effect of competition on the relationships of seed weight and rate of emergence to seedling size, individuals of families were planted in mixed-family blocks at close spacing (4x4 cm), in single (pure) family blocks at close spacing (4x4 cm) and in mixed family blocks at a wide, noncompetitive spacing (16x16 cm). Families differed significantly in seed weight, total emergence percentage and rate of emergence. However, correlations of seed weight to rate of emergence, and seed weight and rate of emergence to seedling size, were not strong. Using germinants was ineffective in diminishing seed effects. Interfamily competition had a minor influence on enhancing the effect of seed traits on seedling growth.

OSU Link
Non-OSU Link

125. St-Clair, J.B. and W.T. Adams. 1991b. Relative family performance and variance structure of open-pollinated Douglas-fir seedlings grown in three competitive environments. Theoretical-and-Applied-Genetics 81(4): 541-550.

Keywords: genetic tree improvement
nursery operations
genetic relationships
growth

Abstract: Open-pollinated Douglas fir (Pseudotsuga menziesii) var. menziesii families were tested in 3 contrasting competitive environments to test the hypothesis that relative performance as measured by total seedling dry weight is dependent upon distance or genotype of neighbours. The 3 environments included (1) a mixture of individuals from all families sown at close spacing, (2) single (pure) family blocks sown at close spacing, and (3) individuals from all families sown at a wide, non-competitive spacing. Despite occasional large changes in rank between competitive environments and only moderate correlations of family means between competitive environments, the family x competitive environment interaction was non-significant. Furthermore, families did not differ significantly in competitive ability or density tolerance. The competitive environment in which seedlings were grown, however, had a large effect on estimates of variance components, which in turn led to large differences in estimates of heritability and genetic gain. Evaluation of families in mixture resulted in the largest estimates of heritability, while evaluation in pure family blocks resulted in the lowest. Analysis of correlated response to selection indicated that testing and selection in mixture resulted in the largest estimated gain, even if progeny of selected individuals are subsequently grown in a pure or non-competitive environment.

OSU Link
Non-OSU Link

126. Stein, W.I. 1984. Wrenching Douglas-fir seedlings in August: immediate but no lasting effects. Pacific-Northwest-Forest-and-Range-Experiment-Station,-USDA-Forest-Service Research-Paper PNW-RP-317. 12 p.

Keywords: nursery operations
tree morphology
growth
carbon allocation
tree/stand health

Abstract: Seedlings in a nursery in Oregon were wrenched in their 2nd growth season in 1976. Wrenched and unwrenched seedlings were sampled at intervals from Aug. 1976 until Jan. 1977, and measured. The entire bed was lifted in Jan. and 100 treated and 100 control seedlings were planted out. After 24 days (Aug.), the number of lateral roots, shoot length, and root dry wt. were significantly smaller in wrenched seedlings. Shoot/root ratio was also smaller and remained so until early Oct. By late Oct., shoot length and the number of lateral roots were significantly greater in wrenched seedlings. During the first 5 yr after planting out, there were n.s.d. between wrenched and unwrenched trees in survival and growth, which were both good.

OSU Link
Non-OSU Link

127. Stein, W.I. 1988. Nursery practices, seedling sizes, and field performance. *In*: Proceedings, combined meeting of the Western Forest Nursery Associations; 1988 August 8-11; Vernon, British Columbia. *Tech Coord.* T.D. Landis. Rocky Mountain Forest and Range Experiment Station, USDA Forest Service General Technical Report RM-GTR-167. 15-18 pp.

Keywords: nursery operations
growth
tree morphology
tree/stand health

Abstract: Highlights are presented from a large cooperative study in Oregon to determine the combined effects of nursery cultural practices on the size and field performance of 2+0 Douglas fir [Pseudotsuga menziesii] seedlings. Seedlings were grown in 3 nurseries using seed from 7 sources; field plantings were made over 3 yr on 28 sites in SW Oregon. Seedbed density had more effect than irrigation frequency, undercutting or wrenching on seedling size, and survival and growth 4 yr after planting.

OSU Link
Non-OSU Link

128. Steinfeld, D., D. Davis, S. Feigner and K. House. 2002. Fall versus spring transplanting of container seedlings: a comparison of seedling morphology. *In* National Proceedings: Forest and Conservation

Nursery Associations 1999, 2000, and 2001, USDA-Forest-Service Rocky-Mountain-Research-Station RMRS-P-24. 196-200 pp.

Keywords: nursery operations
growth
tree/stand health
tree morphology

Abstract: In a study in Oregon, USA, containerized seedlings of Engelmann spruce (Picea engelmannii), sugar pine (Pinus lambertiana), Douglas-fir (Pseudotsuga menziesii), western redcedar (Thuja plicata), and western hemlock (Tsuga heterophylla) transplanted in the early fall and later in the early spring were compared for differences in stem diameter, height, root area, and shoot area. Fall-transplanted Pseudotsuga menziesii and the Thuja plicata showed an increase in stem diameter of 13 (2.0 mm) and 4% (0.4 mm), respectively. Fall-transplanted seedlings developed larger root systems - Picea engelmannii by 18%, Pinus lambertiana by 48%, Pseudotsuga menziesii by 58%, and Tsuga heterophylla by 47%.

Non-OSU Link

129. Stjernberg, E.I. 1997. Mechanical shock during transportation: effects on seedling performance. New-Forests 13(1/3): 401-420.

Keywords: nursery operations
tree physiology
tree/stand health
growth

Abstract: A study was carried out to monitor shocks to seedling planting stock during transport from nursery to the planting site in normal commercial reforestation operations. Size and exact time of mechanical shocks were measured by a recorder placed inside seedling boxes. Seedling shipments by refrigerated semi-trailer, 5-t truck, pickup truck, small trailer and all-terrain vehicles were monitored in Alberta and British Columbia. Number of shocks, peak acceleration and average drop height were tabulated for travel on both paved and gravel roads. Twenty-two trials involving 7 conifer species (Douglas fir, Pseudotsuga menziesii; western hemlock [Tsuga heterophylla]; western red cedar [Thuja plicata]; amabilis fir [Abies amabilis]; white spruce, Picea glauca; lodgepole pine, Pinus contorta; Engelmann spruce, Picea engelmannii) were established at nurseries and field locations covering several ecological zones in both provinces. Frozen-stored, cool-stored, and freshly lifted seedlings were used in the trials. Seedlings were given 2 mechanical stress treatments by dropping them 30 times from 0.5 or 1 m height. Control seedlings were not dropped. Treatments were applied to nursery-trial seedlings not exposed to normal handling and transport, and to field-trial seedlings after transport to the planting site. Six root growth potential tests were made with treated and control seedlings in conjunction with the nursery trials. Seedling survival and volume growth were recorded for two growing seasons and the results are statistically analysed. They indicated that seedlings should not be affected by normal transport and handling activities - some of the shock treatments tested were much more stressful than those resulting from normal procedures. There was some evidence that mechanical shocks could reduce the growth and survival of bare rooted stock, but normal mechanical stresses had no effect on containerized stock. However, it is recommended that care be taken to reduce extreme mechanical shocks during planting stock transportation.

OSU Link
Non-OSU Link

130. Sumaryono and G. Crabtree. 1989. Differential tolerance of woody nursery crop seedlings to napropamide. Weed-Technology 3(4): 584-589.

Keywords: nursery operations
release treatments
chemical release
tree/stand health

Abstract: Field studies at Corvallis, Oregon and greenhouse experiments were conducted to evaluate the tolerance to napropamide of black locust (Robinia pseudoacacia), honeylocust (Gleditsia triacanthos), apple, Douglas fir (Pseudotsuga menziesii), ponderosa pine (Pinus ponderosa) and Japanese black pine (Pinus thunbergii) in the seedling stage. Deciduous species were more susceptible to napropamide than coniferous species. Apple had the slowest seed germination and root development and was more susceptible. The deciduous species had more secondary roots in the shallow soil layer which contained most of the herbicide than the coniferous species. The roots of all woody species tested in vitro were inhibited significantly by contact with the herbicide, but only shoot growth of apple and black locust was inhibited. Injury to woody nursery crop seedlings may be avoided by delaying herbicide application.

OSU Link
Non-OSU Link

131. Tanaka, Y., B. Carrier, A. Dobkowski, P. Figueroa and R. Meade. 1988. Field performance of mini-plug transplants. Rocky-Mountain-Forest-and-Range-Experiment-Station,-USDA-Forest-Service General-Technical-Report RM-GTR-167. 172-181 pp.

Keywords: nursery operations
tree/stand health
growth

Abstract: Mini-plug transplants (MPTs) are grown for 5-6 months in the greenhouse under extended daylength and are transplanted by machine into nursery beds in May when the plants are 4-5 inches tall. Seedlings are grown for one season before planting. Field performance of MPTs was compared with that of other stock types of Douglas fir [Pseudotsuga menziesii] in 6 regions of Washington and Oregon. Based on survival, vigour and height growth, MPTs generally performed as well as or better than other bare rooted stock. Because of their smaller initial height, MPTs had less total height than other stock types after 3 yr. MPTs were not preferred over other stock types in terms of frequency of big-game browsing and rabbit clipping, but, because of their small size, they were unable to withstand heavy animal damage.

132. Thompson, G. 1995. Nitrogen fertilization requirements of Douglas-fir container seedlings vary by seed source. Tree-Planters' Notes 46(1): 15-18.

Keywords: nursery operations

nursery fertilization
growth
carbon allocation
tree morphology

Abstract: Growth of container-grown Douglas fir (Pseudotsuga menziesii) from different seed sources from western Washington, northern Idaho and western Montana was evaluated following application of 100, 150, or 200 p.p.m. nitrogen during the rapid growth phase. The optimum level of N varied between seed sources for height, stem diameter, and bud growth, as well as for root shoot ratio. Target seedling specifications were met adequately for the westernmost sources at 100 and 150 p.p.m. N, whereas eastern sources required 150 or 200 p.p.m. Nitrogen levels should thus be tailored to individual Douglas fir seed sources to maximize the number of shippable seedlings per lot.

OSU Link
Non-OSU Link

133. Trappe, J.M. 1983. Effects of the herbicides bifenox, DCPA, and napropamide on mycorrhiza development of ponderosa pine and Douglas fir seedlings in six western nurseries. Forest-Science 29(3): 464-468.

Keywords: nursery operations
mycorrhizal response

Abstract: The herbicides were each applied (for weed control) at 2 rates to beds of seedlings in nurseries in California, Oregon and Washington. Seedlings were lifted 7-8 months after sowing and the roots examined for mycorrhizae. No herbicide treatment significantly reduced the proportion of feeder roots colonized or the number of mycorrhizal types, compared with controls. Ponderosa pine seedlings treated with DCPA [chlorthal-dimethyl] had a significantly greater proportion of mycorrhizal feeder roots than those treated with the other herbicides (but n.s.d. from controls), and a significantly greater mean number of mycorrhizal types than controls or the napropamide treatment. Douglas fir seedlings treated with napropamide had significantly more mycorrhizal types than those treated with DCPA or bifenox (but were n.s.d. from controls).

OSU Link
Non-OSU Link

134. Trotter, D.B. and G.M. Shrimpton. 1989. Oxyfluorfen (Goal) trials with bareroot forest seedlings in British Columbia 1987. B.C. Ministry of Forestry FRDA Report 092. vi + 22 p.

Keywords: nursery operations
tree/stand health
stand conditions

Abstract: Oxyfluorfen was evaluated at various rates for weed control and crop tolerance on 1+0 and 2+0 bare rooted seedlings of Douglas fir (Pseudotsuga menziesii) and lodgepole pine (Pinus contorta) at Surrey Nursery, British Columbia.

OSU Link
Non-OSU Link

135. Tung, C.H., J. Batdorff and D.R. DeYoe. 1986a. Survival and growth of Douglas-fir seedlings with spot-spraying, mulching and root-dipping. Western-Journal-of-Applied-Forestry 1(4): 108-111.

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

Abstract: In trials near Coos Bay, Oregon, 480 bare-rooted 2+0 Douglas fir seedlings, half of which had roots treated with Terra Sorb (a hydrolysed starch material capable of absorbing large amounts of water), were planted on a harsh site where several regeneration attempts had failed. After planting, seedlings received no further treatment, or glyphosate or paper mulch were applied around seedlings for 1 or 2 yr. Root dipping in Terra Sorb did not enhance survival or growth. Survival was significantly greater after the third season when competing vegetation was controlled with mulch or glyphosate during the first one or two seasons. Survival of seedlings treated twice with glyphosate was 26, 23 and 21% greater, respectively, than seedlings receiving one glyphosate treatment and one or two mulch applications. Ht. growth was n.s.d. among treatments.

OSU Link
Non-OSU Link

136. Tung, C.H., L. Wisniewski and D.R. DeYoe. 1986b. Effects of prolonged cold storage on phenology and performance of Douglas-fir and noble fir 2+0 seedlings from high-elevation sources. Canadian-Journal-of-Forest-Research 16(3): 471-475.

Keywords: nursery operations
tree phenology
tree/stand health
growth
carbon allocation

Abstract: Seedlings of Douglas fir and noble fir (Abies procera) were lifted on 7 Nov. 1981 and 1 Mar. 1982 at Wind River Nursery, Washington, and stored at 1-2 degrees C until planting during the third week of June 1982 at 1500 m alt. in the Oregon Cascade Range. There was no difference in survival of Douglas fir attributable to storage treatment during the first two growing seasons. Noble fir seedlings stored for 7 months survived better during the first season than seedlings stored for 3 months, but no difference was evident after the second growing season. Time of bud burst did not differ between treatments for either species and no difference between treatments in rate of bud burst was seen in Douglas fir. Rate of bud burst was significantly greater in noble fir seedlings stored for 7 months than in those stored for 3 months. Shoot/root ratio decreased significantly during the first season for both species and treatments, but stabilized during the second season. Regardless of species, no differences were found in ht. growth and diam. increment between storage treatments. Results suggest that

seedlings of these species originating from high alt. sources can be lifted in autumn and cold-stored for 7 months without adverse effects on performance after planting.

OSU Link
Non-OSU Link

137. Turner, J. and S.J. Mitchell. 2003. The effect of short day treatments on containerized Douglas-fir morphology, physiology and phenology. New-Forests 26(3): 279-295.

Keywords: nursery operations
growth
tree morphology
tree physiology
photosynthesis
tree phenology

Abstract: The effect of short day treatments ('blackout') on Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) container seedlings at the time of lift and following cold storage was investigated. Variables measured included height, root collar diameter (RCD), root growth capacity (RGC), photosynthetic efficiency after -18 degrees C freezing (PEF), and days to terminal bud break (DBB). From one to four blackout dormancy induction treatments were started on three dates (July 12, July 26, and August 10) with 10 or 20 d between multiple blackouts. Increasing the number of blackout treatments resulted in lower RCD, lower DBB in the late winter/early spring, and higher PEF in the early fall. Later blackout start dates decreased PEF in the early fall, and increased overall height and late fall RGC as compared to earlier blackout start dates. Nurseries growing Douglas-fir seedlings from coastal Pacific Northwest provenances should be aware that blackout regimes can decrease RGC in the late fall, and cause quicker dormancy release in the early spring. Coastal Douglas-fir can be lifted and planted in the early fall, when RGC and DBB are relatively high. If planting between February and April is necessary, seedlings given blackout should be cold stored in January to maintain an adequate level of dormancy, RGC and PEF.

OSU Link
Non-OSU Link

138. Vargas-Hernandez, J.J., W.T. Adams and D.G. Joyce. 2003. Quantitative genetic structure of stem form and branching traits in Douglas-fir seedlings and implications for early selection. Silvae-Genetica 52(1): 36-44.

Keywords: genetic tree improvement
nursery operations
growth
genetic relationships
wood quality

Abstract: Open-pollinated (OP) and full-sib (FS) families of coastal Douglas fir (Pseudotsuga menziesii var. menziesii) were grown in two replicated nursery regimes to evaluate the magnitude and repeatability of genetic parameter estimates for stem form (stem sinuosity, forking) and branching

(number, length and angle of branches) traits in 2-year-old seedlings, and the relationships of these traits with stem growth. With data from older trees of the OP families growing in the field (ages 12 and 24), genetic control of similar traits was compared at the different ages, and nursery-field correlations (rxy) were estimated. With the exception of forking, estimates of family heritability (h2f) were moderate to strong for stem form and branching traits in seedlings (0.32<less or =>h2f<less or =>0.94; mean=0.73), and similar to growth traits (0.45<less or =>h2f<less or =>0.90; mean=0.75). Family performance and estimates of genetic parameters were relatively stable across nursery regimes and family type. Genetic relationships among traits in seedlings were similar to those observed in older field-grown trees, indicating that these traits are controlled by similar sets of genes in the two age classes. Nursery-field correlations between comparable traits were consistent across nursery regimes, but rxy was strong enough to be useful for early testing purposes (i.e. | rxy | <more or =>0.30), only for number of whorls with steep-angled branches (WSAB), branch length, and branch angle in older trees. Predicted gains from early selection for these or correlated traits were at least 40-50% of those expected from selection at older ages. Because of unfavourable genetic correlations, selection for stem growth potential alone at the seedling stage is expected to produce unfavourable impacts on WSAB and stem sinuosity in older trees. To avoid such negative effects on wood quality, both stem form and branching traits should be included as selection criteria in Douglas fir breeding programmes.

OSU Link
Non-OSU Link

139. Wang, X. and D. Zabowski. 1998. Nutrient composition of Douglas-fir rhizosphere and bulk soil solutions. Plant-and-Soil 200(1): 13-20.

Keywords: nursery operations
nursery fertilization
soil properties

Abstract: A study was conducted during 1995-96 at Weyerhaeuser Rochester Seedling Nursery and the White River District of the Weyerhaeuser Tree Farm, Washington, to investigate the nutrient composition of Douglas-fir [Pseudotsuga menziesii] rhizosphere soil solution in soils belonging to the Nisqually and Pitcher soil series, respectively, and to compare rhizosphere solution with that of bulk soil solution. Fertilized (urea, ammonium sulfate, calcium nitrate, and triple superphosphate) and unfertilized Nisqually soils were also compared. Soil solutions were collected using centrifugation. Nutrient concentrations in the rhizosphere solutions were typically higher than that of bulk soil solutions when no fertilizer was applied, but differences in the concentrations of nutrients between the rhizosphere and bulk soil solutions were masked by the addition of fertilizers. With a higher concentration of NH4 relative to NO3 in the rhizosphere soil solution, the solution pH of the rhizosphere was lower than that of the bulk soil, but with a lower concentration of NH4 relative to NO3, the solution pH of the rhizosphere was higher than that of the bulk soil solution.

OSU Link
Non-OSU Link

140. Wheeler, N.C. 1987. Effect of paclobutrazol on Douglas fir and loblolly pine. Journal-of-Horticultural-Science 62(1): 101-106.

Keywords: seed orchard management
nursery operations
growth

Abstract: Paclobutrazol (1.0 and 10.0 mg/10 cc pot) significantly reduced the growth of Pseudotsuga menziesii and Pinus taeda seedlings when applied as a soil drench to newly germinated, container-grown trees. Shoot growth was generally inhibited more than root growth. Older trees (3- to 9-year-old) were not affected appreciably by a soil drench or stem injection. Dose response varied significantly among half-sib families for nearly all growth traits. It is suggested that the utility of paclobutrazol as a growth regulating agent in conifer seed orchards appears to be limited, although it may find use in container-grown conifer nurseries.

OSU Link
Non-OSU Link

141. Wigmore, B.G. and J.H. Woods. 2000. Cultural procedures for propagation of rooted cuttings of Sitka spruce, western hemlock, and Douglas-fir in British Columbia. B. C. Ministry of Forests Research Program Working Paper WP-46. 30 p.

Keywords: nursery operations
growth
reproduction

Abstract: The use of rooted cuttings is explored as a means of bulking-up genetically improved families of Sitka spruce (Picea sitchensis), western hemlock (Tsuga heterophylla), and Douglas-fir (Pseudotsuga menziesii) for reforestation. The number of propagules produced from a small quantity of seed can be multiplied by taking cuttings from seedling stock plants. All methods are developed for 1-year-old cutting production in containers for consistency with most operational seedling production in British Columbia. This report describes cultural techniques for growing stock plants and rooted cuttings of Sitka spruce, western hemlock, and Douglas-fir, based on 3 years of nursery research and observations. It is concluded that 1-year container cutting production is technically feasible for Sitka spruce and western hemlock, but plagiotropism problems (including cuttings with bent stems and those with unflushed terminal buds and bent sub-terminal branches) could not be overcome for the production of 1-year-old cuttings of Douglas-fir. A discussion of plagiotropism is included.

OSU Link
Non-OSU Link

142. Yarris, L. 1983. Cranberry girdlers eat trees, too. Agricultural-Research-USA 31(12): 14-15.

Keywords: nursery operations
tree/stand protection
tree/stand health

Abstract: Field observations and pheromone-trap monitoring carried out in Oregon, USA, by J.A. Kamm & L.M. McDonough showed that adults of the cranberry girdler [Chrysoteuchia topiaria (Zell.)], which is a serious pest of cranberries and grasses, migrated into nurseries of Douglas fir [Pseudotsuga menziesii],

where eggs were laid and the hatching larvae fed on tap-roots, reducing seedling quality and vigour and in some cases killing the seedlings. This problem could be practically eliminated by applying diazinon to nurseries during the flight period of the pest, usually from mid-June to mid-July, followed by 1 or 2 applications of chlorpyrifos to control any larvae. In addition, wherever possible, grasslands bordering a nursery should be re-seeded to a crop on which C. topiaria does not feed, to reduce migration into the nursery, and weeds should be removed from vacant beds and a non-host cover crop planted.

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