

Reproduction

1. 2000. Annual Report 1999/2000 - Pacific Northwest Tree Improvement Research Cooperative. Oregon State University, Oregon, USA. 31 p.

Keywords: genetic tree improvement
tree/stand protection
tree physiology
reproduction

Abstract: Includes highlights of 1998-1999; a note to the cooperative members from Tom Adams; Introduction; Current research on seedling drought physiology of Douglas fir [*Pseudotsuga menziesii*], field drought study - genetics of drought sensitivity in older trees, early testing revisited, miniaturized orchard study, pollen contamination study; activities planned for 2000-2001; list of staff publications and abstracts; and a summary of financial support for the fiscal year 1999-2000.

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2. Barclay, H.J. and Y.A. El-Kassaby. 1988. Selection for cone production in Douglas-fir adversely affects growth. *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. 149-151.

Keywords: genetic tree improvement
genetic relationships
growth
reproduction

Abstract: Cone production and radial growth increment were studied for 8 years in a Douglas fir (*Pseudotsuga menziesii*) seed orchard on Vancouver Island, British Columbia, in 365 trees representing 29 open-pollinated (half-sib) families. Genetic correlations for the two traits were compared for each of the 8 years. Six of the correlations were significantly negative, while the remaining two were significantly positive. The predominantly negative correlation between cone production and growth indicates that selection for one of these two characters will effectively select against the other. The practice of selecting for high cone-producing trees in seed orchards may also be expected to yield slower-growing trees.

[Non-OSU Link](#)

3. Colangeli, A.M., L. McAuley and J.N. Owens. 1990. Seasonal occurrence of potential ice-nucleating bacteria on Douglas fir foliage and seed cones. *New-Forests* 4(1): 55-61.

Keywords: seed orchard management
tree/stand protection
tree/stand health
reproduction

Abstract: Plant frost damage can involve interactions between certain surface bacteria and low temperatures. The bacteria contain glycoproteins, which can nucleate ice above -5 degrees C, thus making the plants on which they live more susceptible to freezing. Preliminary studies to determine if bacteria were present on Douglas fir (*Pseudotsuga menziesii*), and whether they exhibited ice-nucleating properties, are reported. Total bacteria and fluorescent *Pseudomonas* populations were monitored on buds, conelets and foliage of five trees in a Douglas fir seed orchard on Vancouver Island, Canada, in April 1986 and between October 1986 and May 1987, over periods that spanned two pollination seasons. Seasonal variation in bacterial numbers was observed, with highest numbers occurring in late winter and early spring. Bacterial populations active in ice nucleation were found. Bacterial numbers during pollination were higher in 1986 than in 1987. Conelet abortion at pollination was also higher in 1986 (55%) than in 1987 (11%). A relation may exist between bacterial populations and conelet abortion at pollination.

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4. Colangeli, A.M., J.N. Owens and S.J. Morris. 1989. Factors affecting cone and seed production in Douglas fir. BC Ministry of Forests FRDA-Report 057. 19 p.

Keywords: seed orchard management
tree/stand protection
reproduction

Abstract: Reduced seed yield in 1986 on 4 *Pseudotsuga menziesii* trees in a British Columbia seed orchard was associated with inadequate pollination, low pollen vigour or viability, embryo abortion, and early ovule abortion. A study of bacterial populations suggested that there may be a causal relationship between this factor and conelet abortion.

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5. Copes, D.L. and R.A. Sniezko. 1991. The influence of floral bud phenology on the potential mating system of a wind pollinated Douglas-fir orchard. *Canadian-Journal-of-Forest-Research* 21(6): 813-820.

Keywords: genetic tree improvement
tree phenology
reproduction
genetic relationships

Abstract: Reproductive bud phenology was recorded from 1983 to 1989 in a Douglas fir (*Pseudotsuga menziesii*) clonal orchard near Monmouth, Oregon. Potential outcross efficiency was calculated for 20 clones from dates of male and female bud opening and pollination mechanism information. Potential outcross efficiency was limited to a maximum of 58% (1983) to 87% (1987). Cool weather before bud opening of the earliest clones delayed and compressed the breeding period and resulted in a greater percentage of trees having synchronous periods of pollen release and receptive seed strobili. Length of breeding season among years averaged 20 days and ranged from 16 to 27 days. Differences in phenology significantly affected the breeding system because the overall breeding period

of the orchard clones exceeded the 8-day receptive period of individual clones by two or three times, and often prohibited or limited potential outcrossing between the earliest and latest clones. Outcrossing was greatest in clones with intermediate phenology and least in the earliest clones. The breeding system appears to be an almost continuous series of overlapping breeding subpopulations. Each year's breeding subpopulations were different from those of other years because of (1) large shifts in rank order of bud opening by 10 to 20% of the clones and (2) differences in the length of breeding season. Average temperature during March was linearly associated with time of floral bud opening. Geneticists may be able to use average temperature of the 4-week periods prior to opening of the earliest floral buds as a tool to identify seed crops formed during years with compressed breeding seasons. Such seed crops are potentially more diverse than seed crops produced during years with extended breeding seasons.

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6. Copes, D.L. 1992. Effects of long-term pruning, meristem origin, and branch order on the rooting of Douglas-fir stem cuttings. *Canadian-Journal-of-Forest-Research* 22(12): 1888-1894.

Keywords: seed orchard management
reproduction

Abstract: The rooting percentages of cuttings taken from 14 Douglas-fir (*Pseudotsuga menziesii*) clones were examined annually from 1974 to 1988. The trees were 10 and 13 yr old in 1974 and were pruned to 2.0 m in 1978 and 1979 and then recut annually to 0.5, 1.0, or 1.5 m, starting in 1983. The pruned trees showed no evidence of reduced rooting percentage even after 15 yr; average rooting increased from 47% in 1974 to 74% in 1986. Rooting percentage was significantly influenced by tree height. Cuttings collected from 0.5 m tall ramets exhibited better rooting than cuttings from 1.0 or 2.0 m tall ramets, and cuttings from 1.0 m tall ramets rooted better than cuttings from 2.0 m tall ramets. Rooting of cuttings collected from 0.5 m high subinterval zones within trees showed a negative linear relation between rooting percentage and collection height. Cuttings collected from the 0-0.5 m zone rooted 25% better than cuttings from the 1.5-2.0 m zone of the 2-m tall trees. A test of rooting of larger, more orthotropic cuttings gathered from the upper flat surface of pruned ramets indicated that the cuttings from the top rooted significantly less than the smaller, more plagiotropic cuttings from the contiguous side areas (24 vs. 33%, respectively). Meristems of secondary origin showed significantly greater rooting than meristems of primary origin. Comparison of rooting of second-order and first-order meristems of secondary origin indicated that second-order twigs averaged 26% better rooting than the first-order branch tips when the cuttings were collected in January and placed in the rooting beds in February.

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7. Copes, D.L. and M. Bordelon. 1994. Effects of tree spacing and height reduction on cone production in two Douglas-fir seed orchards. *Western-Journal-of-Applied-Forestry* 9(1): 5-7.

Keywords: seed orchard management
planting operations

reproduction

Abstract: Two treatments involving tree spacings (12 and 24 ft) within rows spaced 24 ft apart and height control (topped or not topped at 20 ft) were evaluated in 17- and 22-yr-old coast Douglas fir (*Pseudotsuga menziesii* var. *menziesii*) seed orchards in Oregon. Treatment differences for cone production were not significant because of the large tree-to-tree variation in cone production and, at one orchard, the confounding of location with treatment. Cone production in 1990 averaged slightly more than 2 bushels per tree (range 0 to 11.7 bushels). Average production per 96 linear ft of orchard row was 14.8 bushels.

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8. Crook, R.W. and W.E. Friedman. 1992. Effects of pollen tube number and archegonium number on reproduction in Douglas-fir: significance for seed orchard management. *Canadian-Journal-of-Forest-Research* 22(10): 1483-1488.

Keywords: genetic tree improvement
seed orchard management
reproduction
tree/stand health

Abstract: Analyses of the relations between pollen tube number or archegonium number and the number of fertilization events per ovule (fertilization number) in Douglas fir (*Pseudotsuga menziesii*) growing at a seed orchard near Centralia, Washington, indicated strong trends toward higher levels of simple polyembryony as both pollen tube number and archegonial number increased on a per seed basis. These relations have a significant bearing on the management of conifer seed orchards. Simple polyembryony has been proposed to be an effective means of increasing competition on a per seed basis in conifers and, potentially, the overall fitness of progeny. In conifers, supplemental mass pollination has the direct effect of increasing the number of pollen tubes per ovule. Clonal variation in average number of archegonia per ovule is also likely to exist among conifers. It is proposed that when used together, supplemental mass pollination and selection of clones with high archegonial averages may enhance the fitness of seed orchard progeny.

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9. Edwards, D.G.W. and Y.A. El-Kassaby. 1988. Effect of flowering phenology, date of cone collection, cone-storage treatment and seed pretreatment on yield and germination of seeds from a Douglas-fir seed orchard. *Forest-Ecology-and-Management* 25(1): 17-29.

Keywords: seed orchard management
reproduction
tree phenology

Abstract: The effects were studied of reproductive phenology, date of cone harvest, cone storage and seed pretreatment on yield and germination of seeds from a Douglas fir seed orchard

in Victoria, BC, Canada. Flowering phenology (early, intermediate or late) had no discernible effect on seed maturation. Higher germination and yields of filled seeds were obtained from cones collected in mid-Aug., approximately 2 wk prior to cone opening, than from cones collected just as they began to open. Seeds extracted immediately following harvest germinated better than those from cones stored for 2 months. Seeds from all treatments were dormant and responded to prechilling by exhibiting increased germination rates. The implications of these findings for cone-crop management are discussed.

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10. Edwards, D.G.W. and Y.A. El-Kassaby. 1995. Douglas-fir genotypic response to seed stratification. *Seed-Science-and-Technology* 23(3): 771-778.

Keywords: seed orchard management
reproduction
genetic relationships

Abstract: Douglas fir (*Pseudotsuga menziesii*) responses to stratification duration were studied using wind-pollinated seeds from 15 seed-orchard clones, collected from a low elevation Douglas fir seed orchard in Saanichton, British Columbia, Canada. Germinative parameters (germination capacity, peak value, germination value, and germination rate and speed) were evaluated in response to four stratification periods (0, 3, 5, and 7 weeks). Significant differences among germinative parameters were observed indicating that the five-week stratification period represents the most appropriate treatment in minimizing variation caused by genetic differences. The results indicate that the International Seed Testing Association (ISTA) rules, which focus only on germination capacity, do not provide an adequate expression of seedlot dormancy, and since the rules are aimed at bulked seedlots, genetic differences, which can be large in heterogeneous forest tree seeds, are hidden. The results also demonstrate that extended stratification not only reduces the time in which seedlings become established, but also reduces seedling-emergence variation among parental lines.

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11. 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.

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12. 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 in British 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.

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13. El Kassaby, Y.A., S. Barnes, C. Cook and D.A. MacLeod. 1993. Supplemental mass pollination success rate in a mature Douglas-fir seed orchard. *Canadian-Journal-of-Forest-Research* 23(6): 1096-1099.

Keywords: genetic tree improvement
seed orchard management
reproduction

Abstract: Supplemental mass pollination (SMP) success rate in a mature Douglas fir (*Pseudotsuga menziesii*) seed orchard in British Columbia was studied with the aid of a unique electrophoretically detectable allozyme marker. Four SMP methods were tested during periods of maximum pollen release in 1990: operational applications of pollen (pollen applied once to a branch at average receptivity), and branch applications that were carried out during one, two, or three visits (a first pollen application at maximum receptivity and subsequent applications 2 and 4 days later) were conducted. No significant increase in seed-yield traits (total number of seeds per cone, number of filled seeds per cone and seed efficiency) was observed between wind-pollinated and SMP-treated cones. However, multiple branch visits showed significant increases in SMP success rate (18%) when compared with the operational visit (8%) or the one branch visit (9%) results. No significant increase in SMP success rate was obtained when the number of branch visits was increased from two (17.8%) to three (17.9%). It was concluded that operational SMP has the potential to improve the genetic value of the treated Douglas fir crops even under high pollen load. The degree of improvement is dependent directly on SMP fertilization success and indirectly on the genetic value differential between the supplemented and the orchard's ambient pollen, the frequency of application, and the quality (i.e. viability) of the pollen applied.

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14. 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 (*Pseudotsuga 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 these 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.

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15. El Kassaby, Y.A. and C. Cook. 1994. Female reproductive energy and reproductive success in a Douglas-fir seed orchard and its impact on genetic diversity. *Silvae-Genetica* 43(4): 243-246.

Keywords: genetic tree improvement
genetic relationships
reproduction

Abstract: The relationship between reproductive energy and reproductive success and its impact on clonal female gamete contribution were studied in a clonal *Pseudotsuga menziesii* seed orchard. The effect of among- vs. within-clonal variation on seed-cone crop (energy) and filled-seed yield (success) was determined by partitioning their respective variance components. Clonal gametic representations were expressed using Griffin's [Australian Forest Research (1982) 12, 295-302] parental-balance curves and Crow and Kimura's [An introduction to population genetic theory (1970) New York, USA; Harper and Row Publishers] effective population number. Seed-cone and filled-seed yields produced similar parental-balance curves and female effective population numbers. Although similar parental-balance curves and female effective population numbers were produced, the actual clonal gametic representation differed when the contribution of any set of specific clones were considered. It was concluded that parental-balance curves and female effective population numbers provide a static description of the genetic representation and do not illustrate the dynamics of clonal reproductive outputs.

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16. El Kassaby, Y.A., D.G.W. Edwards and C. Cook. 1990a. Impact of crop management practices on seed yield in a Douglas-fir seed orchard. *Silvae-Genetica* 39(5-6): 226-230.

Keywords: seed orchard management
tree/stand protection
reproduction
tree/stand health

Abstract: The impact of two crop-management practices, supplemental mass pollination (SMP) and overhead cooling, on seed yield in a 13-yr-old Douglas fir (*Pseudotsuga menziesii*) seed orchard was studied in Saanichton, British Columbia. A 2x2 factorial trial of SMP/no SMP and cooling/no cooling was applied. There were no significant differences in potential seed yield per cone, average number of successful fertilizations, and average number of filled seeds per cone between cooling or SMP treatments or combinations. Results indicated that within-orchard pollen cloud was not a factor limiting seed yield. Average number of seeds infested by the Douglas fir seed wasp (*Megastigmus spermotrophus*) larvae was significantly ($P < 0.05$) less when cooling was applied,

indicating that the treatment was effective in disrupting the synchrony between the presence of ovipositing females and developing cones.

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17. El Kassaby, Y.A., D.G.W. Edwards and D.W. Taylor. 1990b. Effect of water-spray cooling treatment in a Douglas-fir seed orchard on seed germination. *New-Forests* 4(2): 137-146.

Keywords: seed orchard management
reproduction
tree phenology

Abstract: As part of an assessment of seed orchard crop management practices, results are given of an experiment undertaken to test the effect of cooling treatment on germination in a 13-year-old full-sib Douglas fir (*Pseudotsuga menziesii*) seedling seed orchard at Saanichton, British Columbia, Canada. Overhead cooling by sprinklers during February-March, used in order to delay flowering, produced non-significant effects on germination capacity, germination rate, germination value, and abnormal germination of seeds. The percentage of variation accounted for by cooling treatment ranged from 0.0 to 1.0%. In contrast, variation among trees within each treatment (i.e. cooled or not cooled) ranged from 28 to 46%. These effects were significant, indicating that each tree has an individual germination pattern. The temporal delay of reproductive phenology caused by temperature manipulation as a result of the cooling treatment was judged to be within the species' biological limits.

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18. El Kassaby, Y.A., A.M.K. Fashler and O. Sziklai. 1984. Reproductive phenology and its impact on genetically improved seed production in a Douglas-fir seed orchard. *Silvae-Genetica* 33(4/5): 120-125.

Keywords: seed orchard management
tree phenology
reproduction

Abstract: Reproductive phenology of buds was monitored for 2 yr in a Douglas fir seed orchard to determine the validity of the theory of panmictic equilibrium. There was a significant variation within clones and families in dates of seed-cone and pollen-cone bud burst, suggesting a major deviation from panmictic equilibrium. This would reduce the size of the breeding population and reduce seed yield. This effect could be reduced, and seed production maximized, either by the use of an irrigation mist system to delay bud development, or by the intensive application of booster pollination.

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19. El Kassaby, Y.A., J. Parkinson and W.J.B. Devitt. 1986. The effect of crown segment on the mating system in a Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seed orchard. *Silvae-Genetica* 35(4): 149-155.

Keywords: genetic tree improvement
seed orchard management
genetic relationships
reproduction

Abstract: The mating system in a mixed clonal/seedling Douglas fir seed orchard was studied by analysing 6 polymorphic allozyme loci. Trees were subjected to cooling treatment to retard bud development and compact the pollination period. The outcrossing rates of upper and lower crown levels and northern and southern crown aspects were estimated and compared for clonal and seedling material separately using single and multilocus methods. Single locus estimates of outcrossing rate ranged from 0.645 to 0.999 and were significantly heterogeneous. No significant differences between the multilocus estimates were observed between crown levels or aspects for either the clonal or seedling material. For all comparisons, the unweighted or weighted single locus means were lower than those obtained by the multilocus method, indicating the presence of other types of consanguineous mating in addition to selfing. In general, higher outcrossing rates were observed in the clonal trees than in those derived from seedlings. The implications of these results for seed orchard management are discussed.

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20. El Kassaby, Y.A. and K. Ritland. 1986. The relation of outcrossing and contamination to reproductive phenology and supplemental mass pollination in a Douglas-fir seed orchard. *Silvae-Genetica* 35(5/6): 240-244.

Keywords: genetic tree improvement
seed orchard management
tree phenology
genetic relationships
economics
reproduction

Abstract: A study was made using allozyme markers of outcrossing and contamination rates in relation to reproductive phenology and supplemental mass pollination in a Douglas fir seed orchard in British Columbia, Canada. Supplemental mass pollination was applied only to the intermediate reproductive phenology class, which showed a high outcrossing rate and no contamination. Both early and late reproductive phenology classes showed significant contamination, but the outcrossing rate for the former was significantly higher than for the latter. These results show that interpretation of seed crop genetic quality based on outcrossing alone could be misleading. The rate and source of contamination, reproductive phenology and crop size should also be considered. The practicability and economics of supplemental mass pollination in avoiding both selfing and contamination are discussed. It was concluded that waterspray cooling and/or supplemental mass pollination of early and late reproductive phenology classes in moderate or good cone-crop years would be an effective management practice. The option of aborting small cone crops in mature orchards is also discussed.

[OSU Link](#)

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21. 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.

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22. Fashler, A.M.K. and Y.A. El-Kassaby. 1987. The effect of water spray cooling treatment on reproductive phenology in a Douglas-fir seed orchard. *Silvae-Genetica* 36(5-6): 245-249.

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

Abstract: The effectiveness of reproductive bud cooling on genetic efficiency in a Douglas fir seed orchard in British Columbia, Canada, was tested by comparing the reproductive bud phenology in 3 cooled and 3 uncooled years. The cooling system was found to affect 2 major elements affecting seed orchard genetic efficiency, namely pollen contamination levels and panmictic equilibrium, as well as insect infestation, frost damage, seed yield and management effectiveness. Based on these results, a permanent irrigation/cooling system is recommended for Douglas fir seed orchards.

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23. Fernando, D.D., J.N. Owens and P.v. Aderkas. 1998. In vitro fertilization from co-cultured pollen tubes and female gametophytes of Douglas fir (*Pseudotsuga menziesii*). *Theoretical-and-Applied-Genetics* 96(8): 1057-1063.

Keywords: genetic tree improvement
reproduction

Abstract: A previous attempt on in vitro fertilization (IVF) in conifers resulted in pollen tube penetration of female gametophytes, but because of the rapid decline in egg viability, no further interaction occurred. It is reported that, for the first time, IVF has been achieved in conifers. Using Douglas fir (*Pseudotsuga menziesii*), a two-step process is described which involved induction of pollen tubes in culture followed by introduction of isolated female gametophytes at the tips of growing pollen tubes. Pollen tubes penetrated the introduced isolated female gametophytes at various places, but a number of tubes entered the egg cell through the neck cells similar to the in vivo condition. Under current culture conditions, longevity of pollen tubes and eggs was improved resulting in the release of sperms, fusion of gametes, and initial formation of the proembryo. Continued plasmolysis of the egg limited the number of successful gametic interactions. IVF has been accomplished in flowering plants in several ways, but the gametophyte-gametophyte IVF system described in here is unique. IVF offers a novel breeding technology that takes advantage of the sexual reproductive route. When coupled with hybridization and genetic transformation, IVF could result in the development of stable novel genotypes of economically superior trees.

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24. Fernando, D.D., J.N. Owens, P.v. Aderkas and T. Takaso. 1997. In vitro pollen tube growth and penetration of female gametophyte in Douglas fir (*Pseudotsuga menziesii*). *Sexual-Plant-Reproduction* 10(4): 209-216.

Keywords: genetic tree improvement
reproduction

Abstract: Pollen tube and female gametophyte interactions in Douglas fir (*Pseudotsuga menziesii*) were examined in vitro. Formation of pollen tubes in Douglas fir occurred on a modified MS medium in which concentrations of H₃BO₃ and Ca(NO₃)₂ were altered and supplemented with sucrose and polyethylene glycol. Addition of 100 micro g/ml H₃BO₃ and 300 micro g/ml Ca(NO₃)₂ resulted in optimum pollen viability. Lack of H₃BO₃ inhibited pollen tube formation. Addition of H₃BO₃ and Ca(NO₃)₂ significantly increased pollen tube formation within one week in culture. Using a medium supplemented with mannitol, viability of Douglas fir pollen can be sustained for 7 weeks in culture, about the same length of time as in vivo. However, pollen tubes are not formed. This suggests that the factors responsible for tube formation reside in the external environment of the pollen. Culture of female gametophytes to examine egg viability and longevity had not been done previously. Egg viability in culture is short-lived, and therefore the window to study and manipulate events of fertilization in Douglas fir is very limited. In spite of this, about 7% of the female gametophytes that were co-cultured

became penetrated by pollen tubes. In vitro archegonial penetration has been repeatedly achieved, but pollen tubes also penetrated other parts of the female gametophytes. Pollen tubes also penetrated non-viable eggs. Most female gametophytes were not penetrated because of pollen tube branching and swelling, failure of tubes to orient towards the female gametophytes, or premature pollen tube death due to plasmolysis. This report outlines the first attempt towards in vitro fertilization in conifers.

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25. Johnson, D.R., G.P. Markin, R.C. Reardon and W.K. Randall. 1984. Injecting Metasystox-R at three spacing intervals to improve seed yield in Douglas-fir. *Journal-of-Economic-Entomology* 77(5): 1320-1322.

Keywords: tree/stand protection
reproduction

Abstract: Injecting oxydemeton-methyl into Douglas firs (*Pseudotsuga menziesii*) using the Mauget Inject-A-Cide technique at 3 spacing intervals in studies in western Oregon in 1982 significantly reduced populations of *Contarinia oregonensis* and increased filled seed yield when compared with untreated controls. Injectors were placed at intervals of 5, 10 or 15 cm of circumference at breast height and delivered 0.1 g a.i./cm of circumference. The results did not differ among the treatments.

[OSU Link](#)

[Non-OSU Link](#)

26. Koerber, T.W. and G.P. Markin. 1984. Metasystox-RReg. injections increase seed yield of Douglas-fir in California, Oregon, and Washington. *In* Proceedings of the cone and seed insects working party conference, Working Party S20701, Southeastern Forest Experiment Station, Asheville, NC. *Ed.* H. Yates, III. pp. 137-146.

Keywords: tree/stand protection
tree/stand health
reproduction

Abstract: Injections of 1.5 g for each 15 cm of tree girth reduced seed damage caused by *Contarinia oregonensis* and *Barbara colfaxiana*, but not that by *Megastigmus spermatrophus* [*M. spermatrophus*]. On sites with insect populations high enough to cause substantial seed losses, treatment increased seed yield per cone by 38-162%.

[OSU Link](#)

[Non-OSU Link](#)

27. 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](#)

28. 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](#)

29. Miller, G.E. 1983b. When is controlling cone and seed insects in Douglas-fir seed orchards justified? *Forestry-Chronicle* 59(6): 304-307.

Keywords: seed orchard management

tree/stand protection
economics
reproduction

Abstract: Two seed orchards in British Columbia were sprayed with dimethoate in 1981, and the costs of estimating crop size and insect infestation and of dimethoate application were recorded. The cost/tree was \$2.31 or \$3.68 (including sprayer rental). Benefit/cost ratios were calculated and plotted against number of cones/tree and varying increases in yield (3-24 filled seeds/cone) due to protection. The number of cones a tree must bear and the increased yield/cone required to cover the cost of one dimethoate application are given in graphs for seed values of \$150-1000/kg.

[OSU Link](#)

[Non-OSU Link](#)

30. Miller, G.E. 1986. Damage prediction for *Contarinia oregonensis* Foote (Diptera: Cecidomyiidae) in Douglas-fir seed orchards. *Canadian-Entomologist* 118(12): 1297-1306.

Keywords: seed orchard management
tree/stand protection
tree/stand health
reproduction

Abstract: Damage to Douglas fir (*Pseudotsuga menziesii*) in British Columbia at cone harvest by *Contarinia oregonensis* was positively correlated with the number of egg-infested scales per conelet in the spring. Reducing the average number of galled seeds per cone by 1.5 increased the average number of filled seeds per cone by 1.0 in insecticide trials. Optimum sample sizes for estimating average densities of egg-infested scales were calculated to be 1 conelet/tree and 150 trees/orchard. The mean crowding variable was linearly related to average density, so a sequential sampling technique relative to a critical density was developed for determining the need for control measures.

[OSU Link](#)

[Non-OSU Link](#)

31. Minore, D. 1986b. Germination, survival and early growth of conifer seedlings in two habitat types. Pacific-Northwest-Forest-and-Range-Experiment-Station,-USDA-Forest-Service Research-Paper PNW-RP-348. ii + 25 p.

Keywords: planting operations
reproduction
tree/stand health
growth

Abstract: Seed germination, and seedling survival and early growth of Douglas fir, western hemlock, *Abies procera* and *A. amabilis* were studied on clear felled sites in the *A. amabilis*/*Achlys triphylla* and *A. amabilis*/*Vaccinium membranaceum*/*Xerophyllum tenax* habitat types in the McKenzie River basin, Oregon. Severe seed predation and high surface soil temp. in both habitat types resulted in almost total seedling mortality during the first season when seeds had been sown on a

few large, consolidated seedbeds. Seedling survival was n.s.d. between habitat types. Survival of Douglas fir (the only species tested) was better when seeds were sown in small scattered spots. Habitat type and addition of forest humus did not affect survival and growth, but shading by stumps and protection from predation using plastic berry baskets were both beneficial. Soils from both habitats had similar colour, texture, pH and nutrient content. In greenhouse studies, seeds of all species began germinating earlier and continued to germinate for longer in soil from Achlys sites than in soil from Xerophyllumsites. It is suggested that unmeasured biological activity may have been responsible for differences in germination activity between the two soil types.

[OSU Link](#)

[Non-OSU Link](#)

32. 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](#)

33. 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](#)

34. 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](#)

35. 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](#)

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36. Ross, S.D. and R.C. Bower. 1989. Cost-effective promotion of flowering in a Douglas-fir seed orchard by girdling and pulsed stem injection of gibberellin A4/7. *Silvae-Genetica* 38(5-6): 189-195.

Keywords: seed orchard management
reproduction
economics

Abstract: In a seed orchard in British Columbia, Canada, Douglas fir (*Pseudotsuga menziesii*) grafts of 5-14 cm diam. received different combinations of partial saw-cut stem girdles and ethanolic solutions of GA4/7 injected into shallow holes drilled around the main stem. Grafts averaged 79 seed-cone buds and 4500 pollen-cone buds each without treatment. Girdling alone increased production per tree of seed- and pollen-cone buds to 325 and 9300 respectively. GA4/7 alone was nearly as effective as girdling alone, the response being marginally greater at the high than low dosage (3.82 vs. 1.27 mg/cm² of stem cross sectional area), but independent of whether the total dose was applied all at once or over two or three injections at 2-wk intervals. Together, girdling and GA4/7 had an additive effect on flowering, increasing production per tree of seed- and pollen-cone buds to 585 and 18250. The combined treatment was particularly effective on smaller trees that flowered poorly or not at all without treatment, while also enhancing production significantly on larger trees. The combined treatment was safe and highly cost effective. It cost \$63.75 per year to maintain each tree in the orchard, so that without any treatment the cost per seed-cone bud initiated was \$0.91. Girdling (at \$2.07 per tree) reduced this cost to \$0.20, and girdling + GA4/7 (at \$7.87 per tree) to only \$0.13.

[OSU Link](#)

[Non-OSU Link](#)

37. Ross, S.D. and R.C. Bower. 1991. Promotion of seed production in Douglas-fir grafts by girdling + gibberellin A4/7 stem injection, and effect of retreatment. *New-Forests* 5(1): 23-34.

Keywords: seed orchard management
reproduction
economics
tree/stand health

Abstract: In a Douglas fir (*Pseudotsuga menziesii*) seed orchard in British Columbia, Canada, in 1985, 12- to 17-year-old Douglas fir grafts received no treatment, stem girdles only (G), or girdles plus stem injection of gibberellin A4/7 (G+GA) at vegetative bud burst. In 1987 they were retreated with G+GA or left untreated. Trees were untreated in 1986 and cone production in 1987 was very sparse. G+GA treatment in 1987 increased 1988 production of seed cones from 465 to 1600 per tree, with a comparable increase in frequency of grafts producing a heavy crop of pollen cones. However, induction treatments applied in 1985 adversely affected seed- and pollen-cone production in 1988, independent of treatment in 1987. Cone size, total and filled seed per cone, and seed germination were little affected by treatment in either year. Treatment with G+GA in 1987 only maximized production of filled seeds (48100/tree), although G+GA in both 1985 and 1987 (31200/tree) was still effective compared with no treatment in either year (14700/tree). Application time (about 4.8 minutes per tree for G+GA) and costs

are discussed in terms of seed yield (for biennial treatment, about an extra \$0.17 per additional 1000 filled seeds). Physiological costs to the tree are noted: the G+GA treatment adversely affected tree condition more severely than previously (or since) experienced, probably as a consequence of prolonged late-summer droughts during each of the treatment years. Additional irrigation and fertilizer treatments are suggested to alleviate such stresses.

[OSU Link](#)

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38. Ross, S.D. and R.C. Currell. 1989. Effect of top pruning, branch thinning and gibberellin A4/7 treatment on the production and distribution of cone buds in Douglas-fir. *Silvae-Genetica* 38(5-6): 177-185.

Keywords: seed orchard management
reproduction

Abstract: Three levels each of topping and pruning (in Feb.), with and without stem injections of GA4/7 (during June and July), were replicated in two blocks of a 7-yr-old Douglas fir (*Pseudotsuga menziesii*) seedling seed orchard in British Columbia, Canada. Flowering was assessed the following year and height increment over two years, when the study was accidentally terminated by management activities. In one orchard block, topping trees from six whorls of branches to five or three whorls depressed female and male flowering disproportionately relative to contributions of the removed crown regions in untopped trees. Trees in the other block were less vigorous and fecund. Here the light topping also depressed female and male flowering but only in proportion to its severity. Heavy topping increased production of seed cones relative to untopped trees and had no effect on male flowering. Pruning of interwhorl and/or smaller whorl branches depressed female flowering in approximate proportion to the branches' contribution in unthinned trees, but had a disproportionate effect on pollen-cone production. Results are discussed in relation to the hypothesis that flowering response to topping and pruning is a function of the vegetative vigour response of shoots following release from apical control. Treatment with GA4/7 increased the production of seed- and pollen-cone buds by 161% and 91% respectively, although seed-cone abortion was also 35% higher in GA4/7-treated trees. A modified stem injection method for the operational GA4/7 treatment of Douglas fir seed orchards is discussed.

[OSU Link](#)

[Non-OSU Link](#)

39. Ross, S.D., J.E. Webber, R.P. Pharis and J.N. Owens. 1985. Interaction between gibberellin A4/7 and root-pruning on the reproductive and vegetative process in Douglas-fir. I. Effects on flowering. *Canadian-Journal-of-Forest-Research* 15(2): 341-347.

Keywords: seed orchard management
reproduction

Abstract: In two seed orchard trials in Washington State and British Columbia, profuse female flowering was induced in young, but ontogenetically mature grafts of inherently poor-flowering clones (1979) and in 9- and 10-yr-old seedling-origin trees of both good- and poor-flowering families (1981) by the cultural treatment of root-pruning in conjunction with stem injections of the gibberellin A4 and A7 (GA4/7)

mixture. Promotion of male flowering, however, was confined to the more sexually mature grafts. As an individual treatment in the 1981 study, root-pruning was more effective than GA4/7, particularly for the poor-flowering families which did not respond well to GA4/7 alone. The two treatments combined had a highly synergistic effect on both male and female flowering, the synergism being relatively greater for the poor-flowering than for the good-flowering families. Although GA4/7 was not tested alone on grafted propagules, its use with root-pruning enhanced an already significant increase in seed- and pollen-cone buds from root-pruning alone by 540 and 92%, respectively. Both these and subsequent trials have shown combined root-pruning and GA4/7 to be a most effective cone-bud enhancement treatment for use in young Douglas-fir breeding and seed production orchards.

[OSU Link](#)

[Non-OSU Link](#)

40. 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 [*Megastigmusspermatrophus*] 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](#)

41. 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](#)

42. 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](#)

43. St-Clair, J.B. and W.T. Adams. 1993. Family composition of Douglas-fir nursery stock as influenced by seed characters, mortality, and culling practices. *New-Forests* 7(4): 319-329.

Keywords: genetic tree improvement
reproduction
growth
genetic relationships

Abstract: Changes in family composition during nursery production were evaluated by following individual seeds and seedlings of 36 wind-pollinated Douglas fir (*Pseudotsuga menziesii* var. *menziesii*) families sown in mixture in two operational nurseries in western Washington and Oregon. Families differed significantly in emergence (measured after 5 wk) and in percentage of seedlings culled for being too small (at end of second growing season: <4 mm stem diameter or <20 cm stem height). Filled seed germination rates (tested in the laboratory) were not related to emergence rates. Differences overall were small enough that family composition was largely unaffected. Observed changes in family composition did not markedly reduce genetic diversity and did not affect the genetic gain that may be expected from an improved population. The plantable nursery stock was, for the most part, representative of the composition of families originally sown.

[OSU Link](#)

[Non-OSU Link](#)

44. Stein, J.D., R.E. Sandquist, T.W. Koerber and C.L. Frank. 1993. Response of Douglas-fir cone and seed insects to implants of systemic insecticides in a northern California forest and a southern Oregon seed orchard. *Journal-of-Economic-Entomology* 86(2): 465-469.

Keywords: seed orchard management
tree/stand protection
tree/stand health
reproduction
stand conditions

Abstract: The systemic insecticides acephate, dimethoate and carbofuran were implanted into *Pseudotsuga menziesii* at Oakridge, Oregon and Willow Creek, California, to evaluate their effectiveness in reducing seed and cone insect damage. The acephate-implant treatment significantly reduced seed damage by *Barbara colfaxiana* and *Contarinia oregonensis*, and significantly increased the percentage of filled seed by 300% at the California site. Neither dimethoate nor carbofuran significantly affected any of the seed or cone insects encountered. Acephate was not effective against *Megastigmus spermotrophus* or *Leptoglossus occidentalis*. The association observed between *C. oregonensis* damage and undeveloped seeds suggested that management strategies that include effective control measures should also include methods to monitor and reduce seed abortion.

[OSU Link](#)

[Non-OSU Link](#)

45. Stoehr, M.U., B.L. Orvar, T.M. Vo, J.R. Gawley, J.E. Webber and C.H. Newton. 1998. Application of a chloroplast DNA marker in seed orchard management evaluations of Douglas-fir. *Canadian-Journal-of-Forest-Research* 28(2): 187-195.

Keywords: genetic tree improvement
genetic relationships
reproduction

Abstract: Pollen contamination, supplemental mass pollination efficacies, and natural selfing were evaluated in a Douglas fir (*Pseudotsuga menziesii*) clonal-row seed orchard near Victoria, British

Columbia, using a genetic marker on the paternally inherited chloroplast (cp) genome. A primer pair for the polymerase chain reaction amplification of a variable region on the cpDNA in Douglas fir was developed. The amplified DNA product was highly variable in size, yielding 13 different haplotype bands from 20 orchard genotypes growing in the clonal-row seed orchard. Observed band sizes ranged from 859 to 1110 base pairs (bp). To estimate variation levels in the orchard background pollen pool, 96 assayed genotypes from surrounding stands gave rise to 36 different haplotypes, ranging from 367 to 1119 bp in size, resulting in a gene diversity estimate of 0.91. Most orchard clones' haplotypes were also present in the background. After adjusting for the presence of orchard-type haplotypes in the background, contamination was found to be 40%. Natural selfing in six individual clones ranged from 0 to 19% with an average of 6%. Supplemental mass pollination efficacy was estimated to be 55%, ranging from 39 to 73%, depending on the maternal clone and flowering phenology. This DNA marker proved to be very useful in assessing seed orchard mating dynamics and orchard management efficacies for Douglas fir.

[OSU Link](#)

[Non-OSU Link](#)

46. Stoehr, M.U., J.E. Webber, C.C.A. Hollefreund and R.A. Painter. 2004. Potential pollen contamination effects on progeny from an off-site Douglas-fir seed orchard: 9-year field results. *Canadian-Journal-of-Forest-Research* 34(4): 981-984.

Keywords: genetic tree improvement
seed orchard management
reproduction
tree/stand health
growth

Abstract: To evaluate the potential effects of seed orchard pollen contamination from surrounding background sources, we made control pollinations with outside orchard pollen and inside orchard pollen on trees of a Douglas-fir (*Pseudotsuga menziesii*) coastal-interior transition zone seed orchard. This zone encompasses the coast mountains from the Washington border to Alaska, USA. The resulting progeny were tested on a transition zone and a coastal site. After nine growing seasons, survival was above 90% on both sites for both pollen sources, and the tree height differences due to pollen source were statistically non-significant. Wildstand operational seedlots, used as controls, were 17% shorter than the contaminated seedlings. Orchard management implications of these results are discussed.

[OSU Link](#)

[Non-OSU Link](#)

47. Stoehr, M.U., J.E. Webber and R.A. Painter. 1994. Pollen contamination effects on progeny from an off-site Douglas-fir seed orchard. *Canadian-Journal-of-Forest-Research* 24(10): 2113-2117.

Keywords: genetic tree improvement
seed orchard management
growth
genetic relationships
reproduction

Abstract: The effects of background pollen contamination were evaluated for first-year height growth pattern of seedlings originating from a Douglas fir (*Pseudotsuga menziesii*) coastal-interior transition zone seed orchard located on southern Vancouver Island, British Columbia. Pollen collected from five stands surrounding the orchard (background pollen) and pollen from five half-sib families of the seed orchard were applied to six individual trees in the orchard. The resulting 60 seed lots were raised outdoors in a coastal-climate nursery with five seed lots collected from wild stands of the transition zone. Heights were measured at 10-day intervals during the growing season. Final heights, maximum height growth rate and growth cessation were subjected to analysis of variance. Growth rate and cessation were derived from data fitted to the logistic growth curve using nonlinear regression analysis. Seedlings sired by the background pollen had significantly greater final heights and growth rates. There were no differences in orchard seedlings in growth cessation probably because all seedlings were exposed to a blackout treatment to force bud set in mid-August. The average final height of wild-stand seedlings from the transition zone was 15% and 21% lower than that of pure orchard seedlings and seedlings sired by the background pollen lots, respectively. Standard deviations for measured traits were similar between orchard seedlings sired by background pollen and orchard pollen. If pollen contamination is not prevented, the faster growing seedlings sired by the background pollen may be preferentially selected during culling in the nursery and outplanted on sites to which they are maladapted.

[OSU Link](#)

[Non-OSU Link](#)

48. Sullivan, T.P. and D.S. Sullivan. 1985. Operational direct seeding of Douglas-fir and lodgepole pine with alternative foods in British Columbia. B.C.-Ministry-of-Forests Research-Note 97. vi + 16 p.

Keywords: planting operations
tree/stand protection
tree/stand health
economics
reproduction

Abstract: Direct sowing of clear-felled areas in temperate coniferous forests of N. America has often been hampered because of seed predation by rodents and birds. In trials in British Columbia, seed predation was considerably reduced when Douglas fir (*Pseudotsugamenziesii*) seed was mixed with sunflower seed (7:1 sunflower to Douglas fir) or with sunflower seed and oat kernels (5:2:1 sunflower/oats/Douglas fir) or when lodgepole pine (*Pinus contorta*) seed was mixed with sunflower seed (2:1 sunflower to pine). The economics of providing alternative food for the predators and operational considerations are discussed.

[OSU Link](#)

[Non-OSU Link](#)

49. Summers, D. and G.E. Miller. 1986. Experience with systemic insecticides for control of cone and seed insects in Douglas-fir seed orchards in coastal British Columbia, Canada. *In* Proceedings of the 2nd Conference of the Cone and Seed Insects Working Party, Station de Zoologie Forestiere, Olivet, France, September 3-5, 1986. *Ed.* A. Roques. pp. 267-283.

Keywords: seed orchard management
tree/stand protection
tree/stand health
reproduction
stand conditions

Abstract: Three systemic insecticides were screened experimentally, and 2 of them used operationally, against cone and seed insects (especially *Contarinia oregonensis*, *Megastigmus spermatrophus* and *Barbara colfaxiana*), in seed orchards of Douglas fir [*Pseudotsugamenziesii*] on Vancouver I., British Columbia. Dimethoate, as a foliar spray, controlled the pests and increased the number of filled seeds per cone, making it the recommended choice. Oxydemeton-methyl, as a foliar spray, was as effective as dimethoate in controlling the insects but appeared less effective in increasing the number of filled seeds. Injections of oxydemeton-methyl were less effective than foliar sprays in controlling insect damage. Acephate as a foliar spray was inconsistent in the level of pest control achieved and as an injection gave poor results; its use was also associated with the development of serious outbreaks of *Adelges cooleyi* [*Gilletteella cooleyi*].

[Non-OSU Link](#)

50. Webber, J.E. 1995. Pollen management for intensive seed orchard production. *Tree-Physiology* 15(7/8): 507-514.

Keywords: seed orchard management
reproduction

Abstract: Artificially increasing pollen supply - supplemental mass pollination (SMP) - to conifer seed orchards has the potential to increase seed yields and improve the genetic worth of seed crops that would otherwise suffer from the detrimental effects of pollen contamination and unbalanced paternal contribution. However, success rates, measured as the proportion of seed fertilized by SMP, have been low. This review examines the concepts underlying SMP and presents data for two SMP field trials [? in British Columbia] with Douglas fir (*Pseudotsuga menziesii*) and white/Engelmann spruce (*Picea glauca*, *Picea engelmannii*). The trial results are discussed with respect to pollen fertility, pollination technique, and competing pollen cloud density. A summary is also given of methods for ensuring the successful handling of pollen ex situ.

[OSU Link](#)

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51. Webber, J.E. and M. Bonnet-Masimbert. 1993. The response of dehydrated Douglas fir (*Pseudotsuga menziesii*) pollen to three in vitro viability assays and their relationship to actual fertility. *Annales-des-Sciences-Forestieres* 50(1): 1-22.

Keywords: seed orchard management
reproduction

Abstract: In vitro viability response of Douglas fir (*Pseudotsuga menziesii*) pollen stored for various periods (1 to several years) was related to actual seed set. Media effects on germination, leaching time

for conductivity and pollen hydration effects for all assays were also studied, and it was found that media type had a significant effect on germination response which, in the time of the test (48 h), appeared to be related to osmotic rather than metabolic effects. Hydrating stored dehydrated pollen for 16 h at 100% RH and 25 degrees C prior to the analysis had a significant effect on improving the response for conductivity and germination, but had no significant effect on respiration. Hydration effects were also apparent on the correlation coefficient (r) using simple linear regression. For unhydrated and hydrated pollen, the r values for assay response and percentage filled seed per cone (%FSPC) were 0.70 and 0.85 for respiration (RESP), -0.36 and -0.86 for percentage leachate conductivity (%COND), and 0.07 and 0.83 for percentage germination (CLASS 1 + 2), respectively. Using non-linear regression models, the coefficient of determination (r^2) values for assay response of unhydrated and hydrated pollen against %FSPC were 0.76 and 0.83 for RESP, 0.24 and 0.82 for %COND, and 0.61 and 0.84 for CLASS 1 + 2 germination, respectively. The regression equations developed for RESP, %COND and germination can be applied to Douglas fir pollen lots when used for controlled crossing pollinations, but may not result in expected seed set values when the pollen lot is also expected to compete with outcross pollen.

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52. Webber, J.E., S.D. Ross, R.P. Pharis and J.N. Owens. 1985. Interaction between gibberellin A4/7 and root-pruning on the reproductive and vegetative process in Douglas-fir. II. Effects on shoot elongation and its relationship to flowering. *Canadian-Journal-of-Forest-Research* 15(2): 348-353.

Keywords: seed orchard management
reproduction
growth

Abstract: [See FA 45, 3761 and previous paper] Shoot elongation and female flowering response were assessed for gibberellin A4/7 (GA4/7) and root-pruning (RP) treatments applied in 1981 to 9- and 10-yr-old seedlings of families with good- and poor-flowering histories in a seed orchard in British Columbia. In families with a poor-flowering history, stem injections of GA4/7 significantly enhanced elongation of third-whorl terminal shoots but produced no flowering response. In families with a good-flowering history, GA4/7 treatment had no effect on shoot elongation but resulted in a significant increase in seed-cone buds. In contrast, root-pruning significantly retarded shoot growth in families with both good- and poor-flowering histories and was also the single most effective treatment for enhancing flowering. Combined, GA4/7 and RP had a synergistic effect on flowering, and GA4/7 partially overcame the inhibition of shoot growth caused by RP alone. These results are consistent with a hypothesis that exogenous and endogenous gibberellins are used preferentially for vegetative growth processes, with increased flowering occurring only after a threshold concentration of effector gibberellins is reached.

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[Non-OSU Link](#)

53. Wheeler, N.C., C.J. Masters, S.C. Cade, S.D. Ross, J.W. Keeley and L.Y. Hsin. 1985. Girdling: an effective and practical treatment for enhancing seed yields in Douglas-fir seed orchards. *Canadian-Journal-of-Forest-Research* 15(3): 505-510.

Keywords: seed orchard management
reproduction
tree/stand health

Abstract: The results are described of 3 girdling experiments carried out over a period of 12 yr (1972-83) in operational Douglas-fir seed orchards in Washington and Oregon. Saw-cut girdles were superior to band girdles for stimulating a cone crop because they were easier to perform, healed faster, and resulted in lower abortion rates in the stimulated crop. Both annual and biennial saw-cut girdle regimes resulted in improved cone yields relative to untreated controls in 4 successive years. Over that same period of time, cumulative response to annual girdling was greater than to biennial girdling, but in certain response years biennial girdling was best. Girdling had no significant effect on numbers of filled seed per cone, filled seed weight, and germination of existing or stimulated crops. There was some indication that repeated girdling increased abortion rates in existing crops but decreased the rate of abortion in the stimulated crop. The long-term effect of repeated girdling on vegetative health and vigour was minor although wounding by girdling increased the incidence of attack by the sequoia pitch moth (*Synathedon sequoiae*) and other pests. Fertilizing with calcium nitrate without girdling did not significantly increase cone and pollen production; with girdling it gave significant increases. It is suggested that flower promotion treatments such as girdling probably improve the genetic quality of orchard seed by creating near-random mating conditions and by pre-empting unwanted pollen sources.

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54. 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.

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[Non-OSU Link](#)

55. Woods, J.H. 1989. Stem girdling to increase seed and pollen production of coast Douglas-fir. B.C. Ministry-of-Forests Research-Note 103. iii + 13 p.

Keywords: seed orchard management
reproduction
tree/stand health

Abstract: In studies on Vancouver Island, British Columbia, grafted ramets and seedlings of Douglas fir (*Pseudotsuga menziesii*) were used to determine the effects of various girdling methods, including complete removal of a band of bark and phloem, opposing partial bands, pruning-saw cuts, aluminium girdling inserts and a single knife cut. Data were collected for 4 yr after treatment on production of seed and pollen cones, tree vigour, girdle wound health and seed characteristics. All treatments appeared to be equally effective in promoting male and female flowering in comparison with ungirdled trees. Treatments did not differ in cone abortion, percentages of filled seeds or seed germination, but there were differences in tree vigour, seed weight and wound healing. A simple knife-cut into the xylem resulted in the least vigour loss and fastest healing. Recommendations are given for girdling procedures using this technique.

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[Non-OSU Link](#)

56. Woods, J.H., T. Wang and S.N. Aitken. 2002. Effects of inbreeding on coastal Douglas fir: nursery performance. *Silvae-Genetica* 51(4): 163-170.

Keywords: genetic tree improvement
growth
tree/stand health
reproduction
genetic relationships

Abstract: In advanced generation seed orchards, low levels of inbreeding may be inevitable as relatedness among individuals in breeding populations increases with each generation. Unlike selfing, low level inbreeding can produce relatively large number of viable seeds. Following previous study on the effects of inbreeding on coastal Douglas fir (*Pseudotsuga menziesii* var. *menziesii*) filled seed production, the present study investigated inbreeding on nursery performance over various cross-types, including outcrosses (inbreeding coefficient $F=0$), crosses between half-sibs ($F = 0.125$), between full-sibs ($F = 0.25$), between parents and offspring ($F = 0.25$), and selfing ($F = 0.5$). Significant differences were found among cross-types for germination, seedling mortality, seedling diameter and height, and nursery cull rate. Inbreeding also increased among-family genetic variability. Cumulative losses of seedlings at the nursery stage were 18, 33, 31, 36 and 43%, respectively for the above types of crosses. This result indicates that seeds with low levels of inbreeding may produce relatively large numbers of seedlings that meet nursery culling standards and could be used for reforestation, resulting in negative impacts on the genetic gain realized in field plantations.

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