

# Genetic control of germination parameters of Douglas-fir, Sitka spruce, western redcedar, and yellow-cedar and its impact on container nursery production

Y.A. EL-KASSABY<sup>1,2</sup>, K. CHAISURISRI<sup>3</sup>, D.G.W. EDWARDS<sup>4</sup>, AND D.W. TAYLOR<sup>4</sup>

<sup>1</sup>Canadian Pacific Forest Products Ltd., Saanich Forestry Centre  
8067 East Saanich Rd., R.R.#1, Saanichton, B.C. Canada V0S 1M0

<sup>2</sup>Faculty of Forestry, University of British Columbia, Vancouver, B.C. Canada V6T 1Z4

<sup>3</sup>ASEAN-CANADA Forest Tree Seed Centre, Muak-Lek, Saraburi 18180, Thailand

<sup>4</sup>Forestry Canada, Pacific Forestry Centre, 506 West Burnside Rd., Victoria, B.C. Canada V8Z 1M5

## 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.

## Résumé

Le contrôle génétique des paramètres de la germination (faculté germinative, maximum et valeur germinative) chez le Douglas taxifolié (*Pseudotsuga menziesii* [Mirb.] Franco), chez l'épinette de Sitka (*Picea sitchensis* [Bong.] Carr.), chez le thuya géant (*Thuja plicata* Donn), ainsi que chez le cyprès jaune (*Chamaecyparis nootkatensis* [D. Don] Spach) a été étudié sur des graines pollinisées par le vent qui provenaient de plusieurs vergers producteurs de graines. L'importance du contrôle génétique sur ces paramètres a été évaluée par détermination d'héritabilité. L'effet du contrôle génétique de ces paramètres sur la diversité génétique des cultures de semis en contenants est évalué.

## Introduction

Forest tree seed orchards and nurseries represent the vehicles for packaging and delivering genetic gains, achieved through selection and breeding, to the field forester. Therefore, the genetic evaluation of these delivery systems (i.e., seed orchards and seedling nurseries) is of great importance to ensure that their purpose is fulfilled in an optimal manner. Studies on several coniferous species seed orchards established the fact that the reproductive output (i.e., seed production) is under strong genetic control and that an orchard's genetic entities (i.e., clones or families) contribute to the resultant seed crops with different proportions (see El-Kassaby 1989; El-Kassaby *et al.* 1989 for reviews). To date, nursery practices have not been genetically evaluated.

Seedlots represent the link in the operations between seed orchards and nurseries. In most cases, these two

operations are being managed independently with minimum interaction. Seed orchardists and seedling growers strive to achieve their respective programs' goals. Although these operations are linked their goals are at variance, and a paradox has emerged: maximizing the diversity in orchard crops is at odds with the uniformity required for large scale seedling production in the nursery.

Bulk seedlots from a seed orchard represent the reproductive output of several parents, each with different proportions, dormancy requirements, germination rates, and germination capacities. The viability of a bulk seedlot is the weighted average of the viabilities of all seed parents. Since seedlot viability is an important parameter for nursery operations, knowledge of the individual parent's germination parameters is also important. (Note: the germination capacity of a seedlot determines the seed sowing factor that should be implemented by the

**Table 1.** Species, seed orchard, number of trees, and year of collection of seedlots used in this study.

Species	Seed Orchard <sup>1</sup>	# of trees	Year of Collection
Douglas-fir (Df)	CPFP	19	1988
Sitka spruce (Ss)	CPFP	18	1989
Western redcedar (Cwr)	FC	22	1989
Yellow-cedar (Cy)	CPFP	12	1989 <sup>2</sup>

<sup>1</sup>CPFP; Canadian Pacific Forest Products Limited, FC; Fletcher Challenge Canada. These seed orchards are located in Saanichton, B.C. (latitude 48° 35' N, longitude 123° 24' W, elevation 50 m).

<sup>2</sup>Seeds collected from 10-month old seed cones (see El-Kassaby *et al.* 1991).

nursery (Vyse and Rudd 1974)). Despite this, very little research has been done on the inheritance of germination parameters of forest tree seeds.

In this paper, we report on the genetic control of germination parameters for four species and its relevance to container nursery production. Seeds used in the study were obtained from seed orchards, i.e., from seed parents growing in a common and uniform environment. Seed pretreatments applied were similar to those used in operational container nurseries. Germination parameters were compared among the four species and among parents within species. The extent of genetic control over germination parameters and estimates of broad-sense heritabilities were determined following Falconer (1986).

## Materials and methods

Orchard-grown seed crops from individual parents (clones and/or families) of four coniferous tree species were used (Table 1). To mimic standard seed pretreatment practiced in container nurseries, seed pretreatment for Douglas-fir and Sitka spruce was a 1-day soak in water at room temperature followed by a 21-day prechilling at +2°C, while for yellow-cedar it was a 1-week soak in water at room temperature followed by 1-month warm (20°C) and 3 months cool (1–3°C) stratification. Western redcedar was germinated without pretreatment. For each species and seed parent, four replications of 100 seeds each were used. All samples, whether prechilled or not, were spread in clear plastic germination boxes lined with moistened cellulose wadding (Kimpak) overlaid with

filter paper, then placed in an incubator set at an alternating temperature of 30°C for 8 h followed by 20°C for 16 h. Light, at approximately 1000 lux, was provided during the high-temperature period by means of cool-white fluorescent tubes (International Seed Testing Association 1985). Germinants were counted on alternate days for 21 days for Douglas-fir, Sitka spruce, and western redcedar, and for 34 days for yellow-cedar.

Germination data were expressed in three ways: 1) germination capacity (GC), 2) peak value (PV), and 3) germination value (GV) (see Table 2 for explanation). Germination parameters (GC, PV, and GV) were analyzed using a simple one-way ANOVA after the appropriate data transformation (Table 2).

## Results

Significant differences were observed among individual seed parents for all three germination parameters, as well as among the four species (Table 2, Figs. 1–4). Estimates of broad-sense heritabilities were relatively high and ranged between 0.91–0.93 for Douglas-fir, 0.42–0.78 for Sitka spruce, 0.78–0.80 for western redcedar, and 0.28–0.42 for yellow-cedar, indicating the presence of high genetic control. Yellow-cedar showed the lowest range while Douglas-fir gave the highest estimates.

Germination capacity (GC), the percentage of seeds that had germinated at the end of the test, varied among seed parents within species and ranged from 26–97%, 90–99%, 59–97%, and 27–68% for Douglas-fir, Sitka spruce, western redcedar, yellow-cedar, respectively

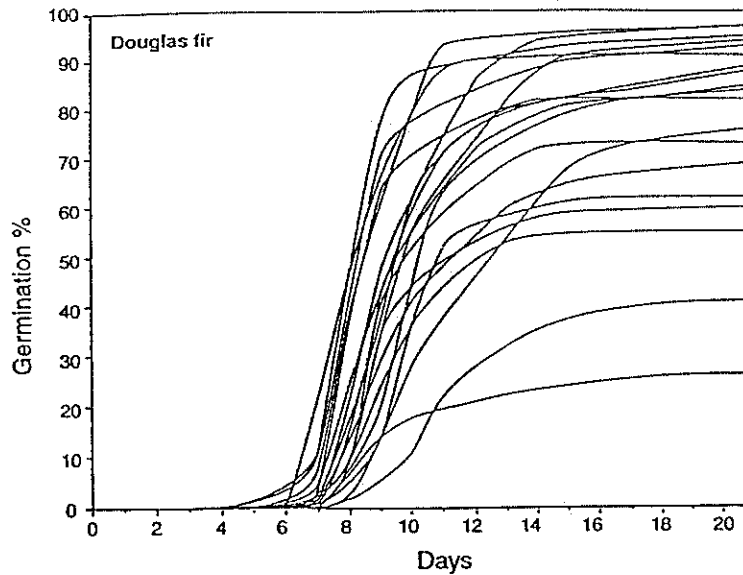


Figure 1. Germination curves for 19 Douglas-fir families. (Source: El-Kassaby *et al.* 1992)

Table 2. Estimates of variance components, significance level, and broad-sense heritabilities ( $h_b^2$ ) for germination parameters of Douglas-fir, Sitka spruce, western redcedar, and yellow-cedar.

Species	Source of variation	Degrees of freedom	Germination parameters <sup>2</sup>		
			GC	PV	GV
Douglas-fir (Df)	Among trees	t-1	0.058**	3.602**	1.681**
	Residual	t(r-1)	0.005	0.348	0.134
	$h_b^2$		0.92	0.91	0.93
Sitka spruce (Ss)	Among clones	c-1	0.003**	0.710**	19.537**
	Residual	c(r-1)	0.004	0.204	6.744
	$h_b^2$		0.42	0.78	0.74
Western redcedar (Cwr)	Among clones	c-1	0.020**	0.521**	23.055**
	Residual	c(r-1)	0.005	0.151	5.733
	$h_b^2$		0.79	0.78	0.80
Yellow-cedar (Cy)	Among trees	t-1	0.014**	0.327*	2.427
	Residual	t(r-1)	0.025	0.829	3.603
	$h_b^2$		0.36	0.28	0.42

\* =  $P < 0.05$ , \*\* =  $P < 0.01$

<sup>1</sup> t = # of trees (Df, t = 19, Cy, t = 12),

c = # of clones (Ss, c = 18, Cwr, c = 22),

r = # of replications = 4.

<sup>2</sup> GC = germination capacity; the percentage of seeds that had germinated at the end of the test (transformation = arcsin).

PV = peak value (Czabator 1962); a mathematical expression of the break of a sigmoid curve representing a typical course of germination (no transformation).

GV = germination value (Czabator 1962); a mathematical expression combining speed and completeness of germination into a single value (transformation =  $\sqrt{(X + 0.5)}$  for Df).

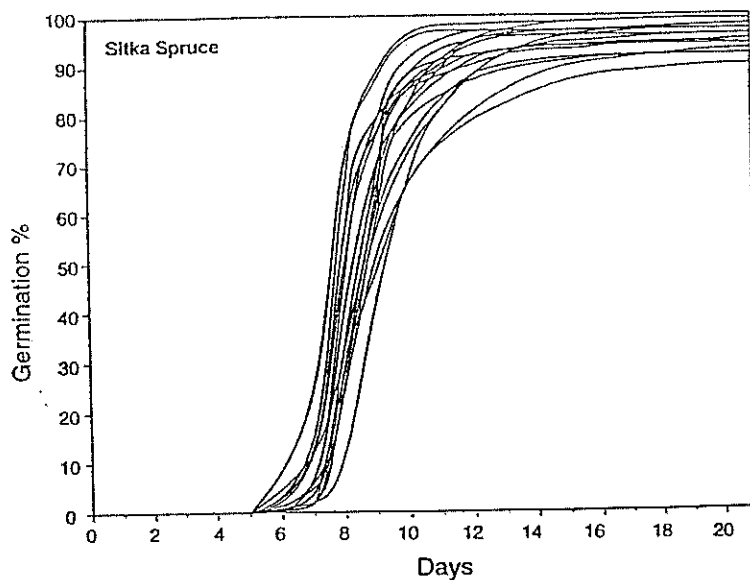


Figure 2. Germination curves for 18 Sitka spruce clones. (Source: Chaisurisri *et al.* 1992)

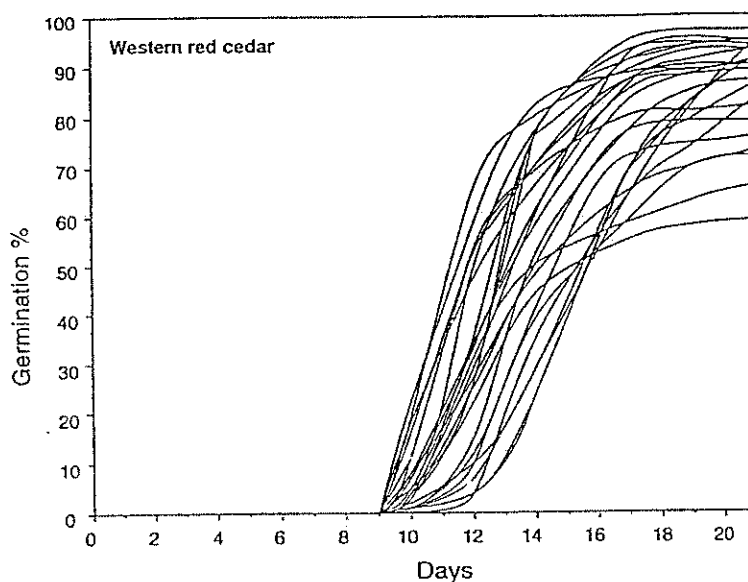


Figure 3. Germination curves for 22 western redcedar clones

(Figs. 1–4). Yellow-cedar showed the lowest germination capacity and germination rate.

### Discussion

Numerous studies have shown a large maternal genetic effect on the germination of several plant species (see El-Kassaby *et al.* 1992, for review) including conifers (Bramlett *et al.* 1983; Hoff, 1987; Davidson 1990; El-Kassaby *et al.* 1992; Chaisurisri *et al.* 1992).

Germination in conifers is the end product of several complex metabolic activities involving three genomes, viz., the seed coat (2n), megagametophyte (1n), and the embryo (2n) (Fig. 5). The maternal contribution of these three genomes is 80% compared to the 20% contributed by the male (Fig. 5). It is to be expected, therefore, that an appreciable amount of variation in seed germination controlled by the dominant, maternal genome will be observed. This variation has been considered to be an adaptation for survival under the temporally heterogeneous environment that is a common feature during germination periods (Jain 1982). The relationships among these genomes (i.e., between maternal-genotype via the seed coat and the other two genomes or between embryo-genotype and the maternal-genotype via the megagametophyte tissue) are sometimes of a conflicting nature. These conflicts have been shown to control the time of germination in Douglas-fir (i.e., the degree of dormancy) (De Matos Malavasi *et al.* 1985).

Seed dormancy varies among species so different seed pretreatments are required. Seed-dormancy differences among families within a species has been reported for western white pine (*Pinus monticola* Dougl.) (Hoff, 1987). In his study, Hoff (1987) also found that improvement in germination varied with duration of stratification. Heit (1961), on the other hand, concluded that stratification (and chemical pretreatment) is not required for germination of Sitka spruce seeds. Yet the present study demonstrates (i) that stratification is essential for Sitka spruce, as well as for Douglas-fir and yellow-cedar, and (ii) that a stratification period of 21 days is inadequate for Douglas-fir (see also Sorensen 1991, Edwards and El-Kassaby in preparation), but that it is adequate for Sitka spruce (Figs. 1–2, 4). In fact, the 1 month warm and 3 months cool stratification used on the yellow-cedar seeds was probably inadequate also, hence the poorer germination.

Sowing prescriptions for any particular seedlot in a container nursery are governed by two major

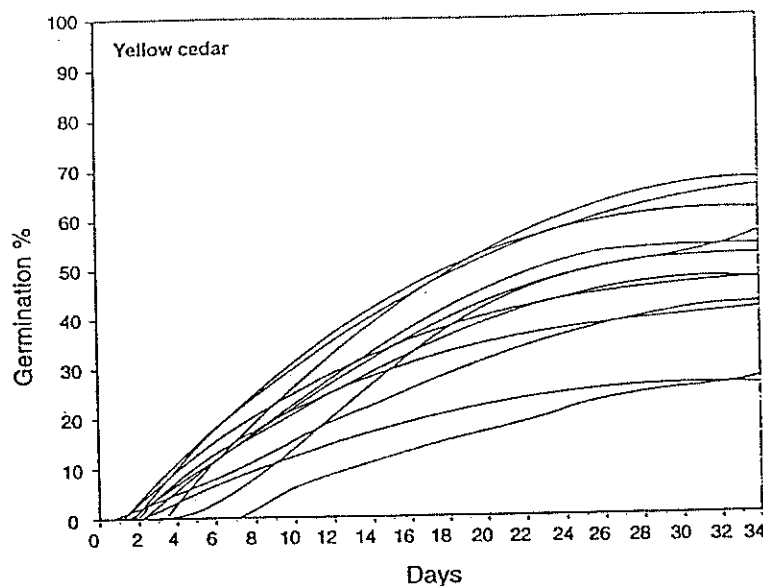


Figure 4. Germination curves for 12 yellow-cedar clones

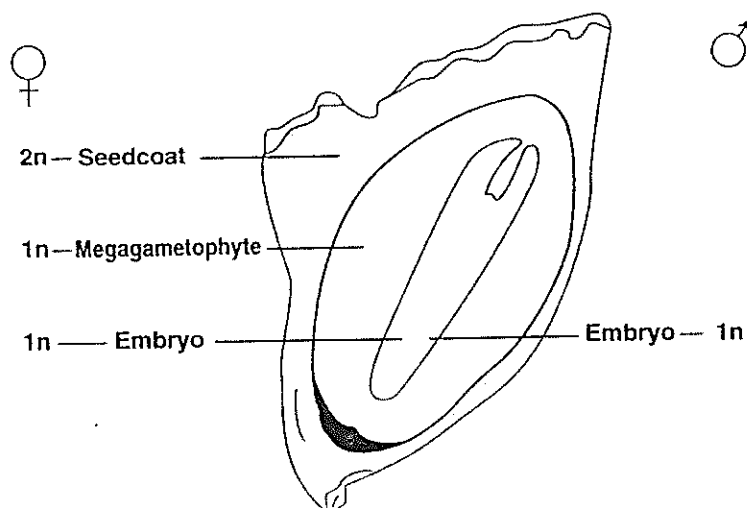


Figure 5. The genomes of a mature Douglas-fir seed.  
(Source: El-Kassaby *et al.* 1992)

considerations, viz., a) the expected proportion of empty cavities and b) the expected proportion of cavities with multiple germinants. When seed viability is low, cavities may be double or triple sown to minimize empty cavities. Yet empty cavities continue to occur. Both empty and multiple-sown cavities represent economic and biological problems to the nursery industry. Empty cavities represent a loss in

productivity, while cavities that were sown with more than one seed may have multiple germinants that require thinning by hand to leave a single germinant.

Thinning practices in container nurseries represent the first step in attaining seedling crop uniformity. In most cases, the germinants that remain after thinning are the largest ones because they are generally the earliest to germinate in the cavity. If seed parents (clones or families) exhibit variation in their germination behaviour, such thinning exerts an inadvertent selection pressure in favor of fast-germinating seed parents.

This selection pressure is also being affected by several other factors. These include: i) the reproductive output of the seed parent in the seed orchard (see El-Kassaby *et al.* 1989), ii) the relationship between reproductive energy and reproductive success (Reynolds and El-Kassaby 1990; Chaisurisri and El-Kassaby 1992), iii) variation in germination capacity (GC, Table 2), and iv) germination speed (represented in this study by PV, Table 2). In nature, all of these factors can be expected to work in concert. For example, if the reproductive output (i.e., the number of viable seeds) of a seed parent is high and these seeds germinate rapidly, then the contribution of this seed parent to the seedling crop can be expected to be high. This has not yet been established and empirical studies are needed for validation.

The high estimates of broad-sense heritabilities obtained in this study demonstrate the presence of genetic variation of germination parameters among the various seed parents for the four species studied and we have speculated on their effect in the nursery. The common practice of harvesting cone crops from seed orchards, extracting the seeds and sowing them on a bulk basis needs to be re-evaluated in light of these findings.

## References

- Bramlett, D.L.; Dell, T.R.; Pepper, W.D. 1983. Genetic and maternal influences on Virginia pine seed germination. *Silvae Genet.* 32:1-4.
- Chaisurisri, K.; Edwards, D.G.W.; El-Kassaby, Y.A. 1992. Genetic control of seed size and germination in Sitka spruce. *Silvae Genet.* in press.
- Chaisurisri, K.; El-Kassaby, Y.A. 1992. Estimation of clonal contribution to cone and seed crops in a Sitka spruce seed orchard. *Ann. Sci. For.* (submitted).
- Czabator, F.J. 1962. Germination value: An index combining speed and completeness of pine seed germination. *For. Sci.* 8:386-396.
- Davidson, R.H. 1990. Patterns of variation in Pacific silver fir (*Abies amabilis* (Dougl.) Forbes) on Vancouver Island. Ph.D. Thesis. Fac. of For., U.B.C., Vancouver, B.C., Canada.
- De Matos Malavasi, M.; Stafford, S.G.; Lavender, D.P. 1985. Stratifying, partially redrying and storing Douglas-fir seeds: effects on growth and physiology during germination. *Ann. Sci. For.* 42:371-384.
- El-Kassaby, Y.A. 1989. Genetics of Douglas-fir seed orchards: expectations and realities. Pages 87-109 in *Proc. 20th. South. For. Tree Improv. Conf., South. For. Tree Improv. Comm. in coop. with Westvaco Corp. and Clemson Univ., Charleston, SC.*
- El-Kassaby, Y.A.; Fashler, A.M.K.; Crown, M. 1989. Variation in fruitfulness in a Douglas-fir seed orchard and its effect on crop management decisions. *Silvae Genet.* 38:113-121.
- El-Kassaby, Y.A.; Edwards, D.G.W.; Taylor, D.W. 1992. Genetic control of germination parameters in Douglas-fir and its importance for domestication. *Silvae Genet.* 41:48-54.
- El-Kassaby, Y.A.; Maze, J.; MacLeod, D.A.; Banerjee, S. 1991. Reproductive-cycle plasticity in yellow-cedar (*Chamaecyparis nootkatensis*). *Can. J. For. Res.* 21:1360-1364.
- Falconer, D.S. 1981. Introduction to quantitative genetics. 2nd ed. New York: John Wiley & Sons, Inc., N.Y. 340 p.
- Heit, C.E. 1961. Laboratory germination and recommended testing methods for 16 spruce *Picea* species. *Proc. Assoc. Off. Seed Anal.* 51:165-171.
- Hoff, R.J. 1987. Dormancy in *Pinus monticola* seed related to stratification time, seed coat, and genetics. *Can. J. For. Res.* 17:294-298.
- International Seed Testing Association. 1985. International rules for seed testing 1985. *Seed Sci. & Technol.* 13:299-513.
- Jain, S.K. 1982. Variation and adaptive role of seed dormancy in some annual grassland species. *Bot. Gaz.* 143:101-106.
- Reynolds, S.; El-Kassaby, Y.A. 1990. Parental balance in Douglas-fir seed orchard—cone crop vs. seed crop. *Silvae Genet.* 39:40-42.
- Sorensen, F.C. 1991. Stratification period and germination of Douglas-fir seed from Oregon seed orchards: two case studies. USDA. For. Serv. PNW-RN-499. 23 p.
- Vyse, A.H.; Rudd, J.D. 1974. Sowing rules for container nurseries. Pages 164-169 in R.W. Tinus, W.I. Stein and W.E. Balmer, eds. *Proc. N. Am. containerized forest tree seedling Symposium, Great Plains Agric. Counc. Publ.* 68.

# **Dormancy and barriers to germination**

**Proceedings of an international symposium of  
IUFRO Project Group P2.04-00  
(Seed Problems)**

**Victoria, British Columbia, Canada  
April 23–26, 1991**

*Compiled and edited by*  
D.G.W. Edwards

Forestry Canada  
Pacific Forestry Centre

1993

