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Parental Balance in Douglas-fir Seed Orchards – Cone Crop vs. Seed Crop*)

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Abstract

Parental balance based on seed-cone and filled-seed crops were estimated and compared for 30 Douglas-fir [*Pseudotsuga menziesii* (MIRB.) FRANCO] trees from a coastal clonal/seedling seed orchard. Estimates based on cone crop differed from results obtained from filled-seed production. It was demonstrated that parental balance based on seed-crop data provide a more accurate assessment of the genetic diversity and the family representation in the resultant seed crop than those based on cone crop. Individual clone or open-pollinated family cone harvest and seed extraction are recommended.

Key words: Douglas-fir, seed orchard, parental balance, cone and seed crop.

Introduction

Parental balance, the equality of male and female strobili production, and reproductive synchrony are fundamental pre-requisites for the production of seeds that reflect the genetic diversity present in seed orchards. It has been demonstrated that these two pre-requisites were not fulfilled in many seed orchards of different species (POLK, 1966; ERIKSSON *et al.*, 1973; JONSSON *et al.*, 1976; GRIFFIN, 1982, 1984; O'REILLY *et al.*, 1982; SCHMIDTLING, 1983; EL-KASSABY *et al.*, 1984, 1986, 1988; BYRAM *et al.*, 1986; SCHOEN *et al.*, 1986; FASHLER and EL-KASSABY, 1987).

Several seed orchard management practices have been proposed to alleviate that departure from expectations. These include: the use of over-head cooling treatment (FASHLER and EL-KASSABY, 1987), supplemental mass pollination (EL-KASSABY *et al.*, 1986, 1988), cultural and/or hormonal treatments (ROSS, 1978; PHARIS *et al.*, 1980; ROSS *et al.*, 1985; WHEELER *et al.*, 1985), and where possible, the mixing of crops of different years (EL-KASSABY *et al.*, 1988).

Parental balance in seed orchards commonly is assessed by cumulative cone-yield curves (GRIFFIN, 1982). In this method the seed orchard's genetic entities (clones or open-pollinated families) are ranked from high to low cone yield and cumulative percentage calculations are plotted against the number of clones or open-pollinated families censused. This method assumes that reproductive energy is equal to reproductive success (i.e., the number of filled seeds per cone is equal across the different parental groups). In this study, the parental balance of 30 Douglas-fir [*Pseudotsuga menziesii* (MIRB.) FRANCO] trees from an 18-year-old clonal/seedling orchard is examined for cone production versus filled-seed production.

Materials and Methods

Canadian Pacific Forest Products Limited's 3.4 ha, "high-elevation" coastal Douglas-fir seed orchard located at the Saanich Forestry Centre near Victoria, B. C. (lat. 48°35' N, long. 123°24' W) provided the material for the study. The orchard consists of a combined clonal/seedling breeding population with 61 clones and 37 open-pollinated families. The trees are planted in a randomized/incomplete block design at 4 × 6 m spacing replicated 16 times (blocks). The ages of the clonal propagules and seedlings are 22 and 19 years, respectively.

The 1987 cone crop (good cone year) was managed with a combination of over-head cooling (FASHLER and DEVITT, 1980) and supplemental-mass-pollination (SMP) treatments. The over-head cooling has proven to reduce pollen contamination levels (EL-KASSABY and RITLAND, 1986), improve panmixis (FASHLER and EL-KASSABY, 1987), and reduce insect and frost damage (MILLER, 1983; FASHLER and EL-KASSABY, 1987). SMP involved blowing on dry pollen mixes representing equal volumes from at least 12 different donors (i.e., open-pollinated families and/or clones). To account for within-tree variation, receptive trees were pollinated two to three times and at two levels: the upper crown, reached by manlift, and the lower crown, reached by ground crews.

During harvest (September 1987), seed-cone crops were collected completely from 30 trees representing 30 open-pollinated families (i.e., one tree/open-pollinated family). The number of seed cones was recorded and, where possible, a sample of five to eight cones was taken at random from each tree for seed extraction. Cone samples were air dried at room temperature, seeds were extracted, dewinged and cleaned by hand. The average number of filled seeds per cone was estimated for each tree by dividing the total number of filled seeds by the number of cones. Filled and empty seeds were determined by cutting each seed individually. The total number of filled seeds per tree was estimated by multiplying the average number of filled seeds per seed-cone by the number of cones harvested per tree.

The relationship between seed-cone crop and filled-seed production was assessed using Pearson's product-moment correlation and Spearman's rank correlation (SOKAL and ROHLF, 1969).

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Results and Discussions

The relationship between seed cone and filled-seed production is expected to be significant and positive. The product-moment correlation between cone and seed crops was positive and significant ($r = 0.62$, $n = 30$, $P < 0.01$). The r^2 (coefficient of determination) on the other hand, was low ($r^2 = 0.39$), indicating the presence of a large amount of variation in the data was not expressed by the relationship between cone and seed production. In fact, the number of seed cones produced by the 30 trees sampled varied between 2 and 646 cones, while the estimated average number of filled seeds per cone ranged between 2.7 and 45.0. *Figure 1* demonstrates that the reported variation in seed-cone (cone crop) and filled-seed (seed crop) production is caused by changes in the rank order between cone and seed producers. The rank order of the 30 sampled trees based on their cone production compared to that produced based on seed crop (filled seed) further explains the observed low r^2 value obtained (*Figure 2*).

Five out of the top ten cone-producing trees remained among the top ten seed producers, while the other five dropped to "intermediate" seed production (rank 11 to 20). The change in rank among the 10 intermediate cone producers indicated the presence of high (11, 14, 16 to 18), intermediate (12 to 13, 15, 20), and low (19) seed producers.

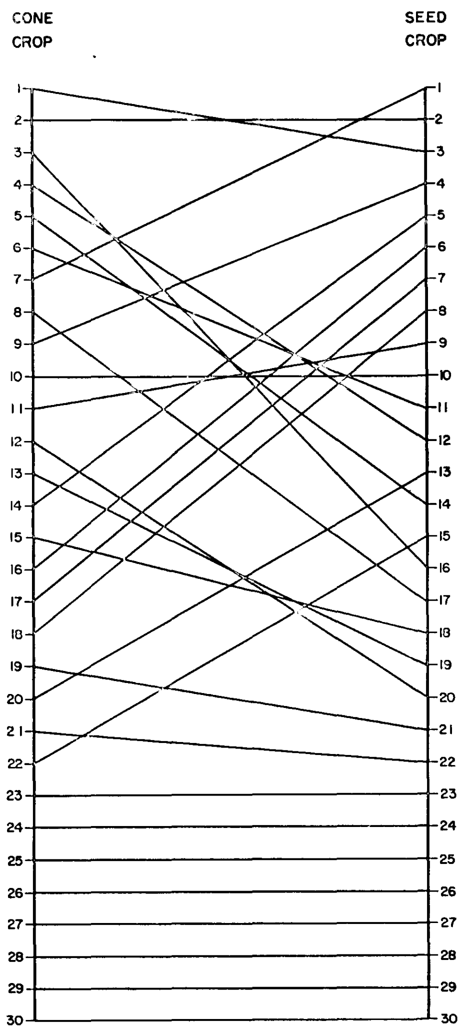

Figure 1. — Rank order presentation for thirty Douglas-fir trees based on cone and seed crops.

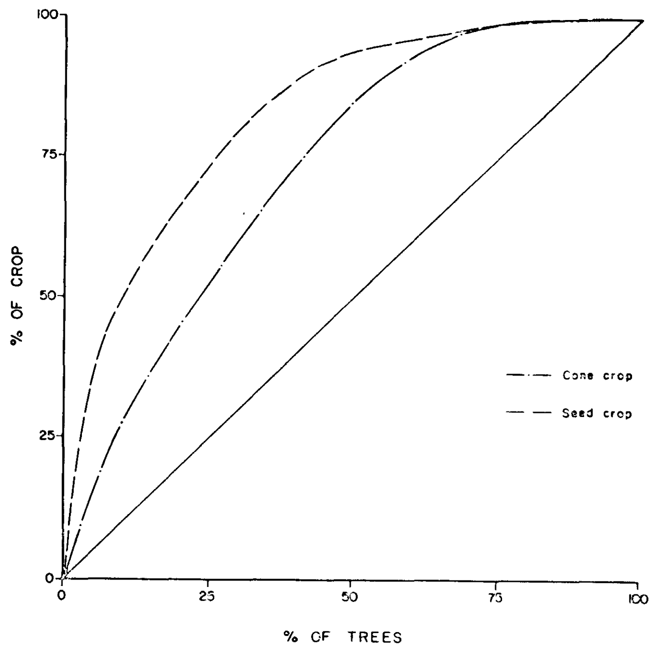

Figure 2. — Cumulative cone and seed production curves for thirty Douglas-fir trees. Straight line represents equal contribution.

On the other hand, nine out of the ten "low" cone producers maintained their relative rank as seed producers.

Spearman's rank correlation gave a significant coefficient ($rho = 0.76$, $n = 30$, $P < 0.01$) indicating that the observed change in ranks between cone and seed production is not significant, however, when the correlation was estimated after the removal of the eight "low" trees (23 to 30) a non-significant rank coefficient ($rho = 0.39$, $n = 22$) was observed, indicating that: a) the change in ranks is significant and b) the observed significant coefficient obtained from the 30 trees was due to the inclusion of those eight trees in the analysis. (Notice that these eight trees did not change their relative rank order under cone versus seed production.)

If parental balance is evaluated based on the cone crop (*Figure 2*), then 90 % of the crop is being produced by 57% of the trees. On the other hand, if it is estimated based on seed production (*Figure 2*), then 90% of the crop is produced by 40% of the trees. Comparing results of parental balance based on cone and seed production indicates the following: 1) the estimate based on cone harvest production under-estimated the distortion in the seed crop from the ideal situation (area between the straight line and the curves), 2) 90% of the cone crop is obtained from 17 trees, while 90% of the seed crop is obtained from 12 trees (a smaller genetic base), 3) the tree that ranked number 8 in seed production is among those producing the 90% of the seed crop, but it was not among those producing 90% of the cone crop (different genetic representation), and 4) there was little rank change in the "low" cone and seed producers.

Douglas-fir cones have the ability to develop to full size even if they have not been pollinated, therefore, estimating parental balance based on a cone count alone could give misleading estimates of both seed crop size and the genetic representation in the resulting seed crop.

Bulk collection of seed orchard seed may have a substantially different genetic makeup over years (see El-

Kassaby *et al.*, 1989), therefore it is recommended to conduct cone harvesting and seed extraction, and where possible, sowing in the nursery on an individual clone or family basis. If the individuality of clones or families is maintained throughout the seed harvest and nursery operation, both the genetic gain and diversity could be maximized through seed and seedling production phases (Lindgren and El-Kassaby, 1989).

Finally, it must be emphasized, that the aim of this note is to demonstrate that parental balance, based on the levels of cone and seed production, differed due to variation between reproductive energy and reproductive success among the orchard's entities. The examination of within-clone and/or open-pollinated families regarding cone versus seed productin is of interest. This will determine how much the cone versus seed crop varies when entire orchard crops are considered.

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Pressemitteilung

Klaus Stern — Förderpreis in Forstgenetik

Am 8. Dezember 1989 verlieh der Forstwissenschaftliche Fachbereich den von der Forstbaumschule Pein & Pein in Halstenbek gestifteten Preis, welcher einen jungen Forstmann in die Lage versetzen soll, während eines längeren zusammenhängenden Zeitraums im Ausland neue Arbeitsmethoden und Erkenntnisse der Forstgenetik kennenzulernen und der Wissenschaft und Praxis in Deutschland zugänglich zu machen. Der Preis trägt den Namen von Professor Klaus Stern, welcher nach seiner früheren Tätigkeit beim Institut für Forstgenetik der Bundesforschungsanstalt für Forst- und Holzwirtschaft von 1966 bis 1973 den Lehrstuhl für Forstgenetik und Forstpflanzenzüchtung an der Universität Göttingen innehatte. Der Preis wurde im Rahmen einer Veranstaltung in der Aula durch den Präsidenten der Universität, Professor Norbert Kamp, verliehen. Bei der Veranstaltung würdigte Professor Langner, der frühere Leiter des Instituts für Forstgenetik, der Bundesforschungsanstalt für Forst- und Holzwirtschaft, das Werden und Wirken von Klaus Stern. Er hob hervor, wie neu für die damalige Zeit seine Gedanken gewesen sind, und wie vielseitig Stern vorgegangen ist, um Erkenntnisse für die Forstgenetik abzuleiten. Danach ging Dr. Neugebauer als Gesellschafter der Stifterfirma auf die engen und vielfältigen Beziehungen zwischen Forstpflanzenanzucht und Forstgenetik ein. Professor Melchior, ebenfalls ein früherer Leiter des Instituts für Forstgenetik der Bundesforschungsanstalt, sprach über die Aussichten für die Forstpflanzenzüchtung. Er verglich die Entwicklung des weltweiten Bedarfs an bestimmten Holzprodukten mit den Möglichkeiten der Forstpflanzenzüchtung, betonte aber bei allem Streben nach wirksamer züchterischer Auslese von den dabei zu leistenden Verzichten. Anschließend stellte Professor Hattemer von der Abteilung für Forstgenetik und Forstpflanzenzüchtung das Fortwirken von Klaus Stern's Ideen dar. Die von Stern gegebenen Impulse haben in der Populationsgenetik von Holzpflanzen auf die grundlegende Bedeutung der Analyse des Paarungssystems aufmerksam gemacht. Durch sowohl theoretische als auch experimentelle Untersuchungen mit chemischen Markern wurden vor 2 Jahrzehnten die Zusammenhänge zwischen Pollentransport, Fertilität und anderen Elementen des Fortpflanzungssystems von Bäumen in ihrer genetischen Bedeutung erstmals herausgestellt. Diese Untersuchungen werden heute in großem Maßstab unter Verwendung