The investment necessary for a suitable irrigation system can be more than justified when considering the investment already made in selection and propagation, seed orchard establishment and the value of the increased genetic gain from orchard seed. The irrigation system is also multipurpose (providing the possibility for frost protection, irrigation, fertilization and cooling), and thus it greatly reduces the expense of water-cooling as a method of eliminating pollen contamination.

Further work is required on irrigation system calibration and determination of the system's effectiveness for frost protection. To improve seed set and possible quality it is recommended to do supplementary or booster pollination using pollen collected from orchard trees.

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The Importance of Flower Phenology in Seed Orchard Designs

by

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Introduction

In order to enhance seed orchard development, a number of basic suggestions have been made recently by Weir and Zobel (1975). They recommended that for 1.5 generation type seed orchards:

- a) the breeding population size should be 30 to 50 clones,
- b) the minimum size should be 4 ha,
- c) spacing should follow the expected shape and development of species and should be on a rectangular grid system,
- d) selfing should be minimized,
- e) panmictic equilibrium should be maximized.

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While the first four recommendations lend themselves to more less easy acceptance and implementation, the last one usually is more difficult to achieve. Frequently it is only more of a hope than a fact that the clones included will have the opportunity to cross in all possible combinations with equal frequency.

As seed orchard designs become more complicated there is an increasing demand to produce seed orchard layouts by computers. One of the latest computer organized orchard layouts (COOL) is based on the permuted neighbourhood design concept (Bell and Fletcher 1978), and assumes that all possible crosses should occur with similar frequency to obtain panmixis.

The program, however, does not consider the variability in reproductive bud development. For example, in case of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), variation in the phenological development of early and late

flowering trees could be as much as 38 days during the same year among individuals in the same population (Griffith 1968). Since the receptivity of female flowers usually does not extend to more than five to six days (Barner and Christiansen 1962; Allen and Owens 1972) under normal climatic conditions, the chance of panmixis could be reduced substantially when plus trees selected from different seed zones are placed in a seed orchard.

A trial orchard layout using the COOL system with clones of varying flowering phenology was used to test the hypothesis that phenological development is an important consideration in seed orchard designs.

Materials and Methods

Thirty-six trees, representing six early, seven late, and 17 average flowering individuals (Table 1) were selected from one population of 154 Douglas-fir trees studied over a ten-year period at the University of British Columbia Research Forest (Griffith 1968).

Based on the 10-year observation, tree no. 96 was the earliest flushing tree with 91 days, while tree no. 40 flushed 128 days after January 1. The range in this case amounted to 37 days, which is not unusual for Douglas-fir.

The control commands for COOL specified a simple, square 10 x 20 m seed orchard layout with 30 clones and maximum 15 ramets in each clone.

Result and Discussion

Between 11 and 15 ramets for each of the 30 clones were used in the seed orchard layout to fill the 400 positions. Early, average and late flowering clones were distributed at random for the permuted neighbourhood design, namely:

- a double ring of different clones isolated each ramet of the same clone, and
- any combination of two adjacent clones occurred in any specific direction only once (Giertych 1975).

Assuming that the most receptive period for successful pollination lasts only up to six days, the question now becomes how well the flowering times of the various clones are synchronized to allow for panmixis to occur. An arbitrary

Table 1. Average 1958 to 1967 flushing dates of some early, average and late flushing Douglas-fir trees.

Flushing type	No. of Trees	Days from January 1
Early	6	96.3
Average	17	111.7
Late	7	123.1

Table 2. Probability of pollination from crosses of three selected clones with different flowering times.

	Probability of Pollination	Total Number of Crosses	Percentages
Early Clone			
No. 14	none	21	73
	some	3	10
	all	5	17
Average Clone			
No. 147	none	15	52
	some	—	—
	all	14	48
Late Clone			
No. 33	none	20	69
	some	3	10
	all	6	21

sample of three clones representing one early, one average, and one late flowering tree was selected to determine the probability of the various possible crosses occurring.

Each clone had a total of 29 different adjacent crosses, and the probability of pollination separated into three arbitrary classes as "none", "some", and "all", is listed in Table 2.

Using three sample clones as representative of the trend for early (no. 14), average (no. 147), and late (no. 33) flowering trees the probability for pollination in the designed seed orchard was calculated (Table 2). Using a weighted average for the six early, seven late and seventeen average flowering trees in the designed seed orchard, approximately 60% of all possible crosses have little or no probability for pollination, which indicates that the assumption of panmictic equilibrium is not fulfilled. A further 36% of the total number of crosses have a high probability for achieving pollination.

These crosses represent early x early, average x average, and late x late combinations. The remaining 4% of the crosses have some overlap in flowering times.

The results of this study indicate that including clones with widely ranging flowering times in the same seed orchard in which wind pollination is the desired means for seed production, as is usually the case in Douglas-fir seed orchards, will substantially reduce the number of effective crosses, could increase inbreeding, and consequently could reduce seed yield. It also increases seed orchard costs, since certain clones are maintained which do not contribute to the "genotypic element" of the orchard. This situation could be improved by:

- modifying the program to ensure greater overlap in flowering times for adjacent crosses,
- avoiding use of very early and very late clones in the same orchard,
- reducing the range of phenological differences in flowering time by using water spray application, and/or
- implementing artificial pollination.

More information is needed to accommodate seed orchard design to panmictic equilibrium. The importance of knowing the phenological characteristics of each clone appears to be essential in future seed orchard development.

A computer-organized orchard layout design was tested using the permuted neighbourhood design concept. Thirty trees were selected with early, average, and late flowering phenological characteristics. Comparing the flowering times of crosses with nearest adjacent neighbours indicated that the panmictic equilibrium was not achieved. Approximately 60% of all possible crosses have little, or no, probability of being completed under natural conditions.

Four suggestions to enhance all possible combinations of crosses were made. The need for further phenological research was stressed.

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