diameter class over thinned control and (2) fertilization did not appear to have any influence on mortality; (c) *a comparison of thinned and unthinned stands*—(1) at the control level, a far greater percentage of stems occurred in the 7.6-cm diameter class in the thinned than in the unthinned plots regardless of fertilizer treatment, (2) combined thinning and fertilization increased the percentage of stems in the 10.2-cm diameter class over unthinned control or unthinned but fertilized, and (3) mortality was generally lower in thinned than in unthinned stands.

Effect on height and diameter growth was evaluated further by selecting the 10 trees with the largest diameters on each plot and comparing mean dbh and height by treatment (Table 3). Mean diameter for these trees was greater in thinned than in unthinned plots and tended to increase slightly with increasing fertilizer levels. Conversely, total height in 1975 and periodic height increment were generally greater in the unthinned than in the thinned plots. A similar response pattern was observed when a larger sample based on the 1975 data and comparing all trees > 3.8 cm was used (Table 3).

The lack of a positive response and the indication of a negative response by jack pine with respect to height increment in the present study is consistent with negative responses reported by Berry (1969) for 10-year-old red pine. Conversely, Chrosiewicz (Bi-mon. Res. Notes 27:6, 1971) reported improved growth of 10-year-old jack pine when stand density was reduced to a moderate density of 4,800 trees/acre (11,856/ha) from an extreme density of 338,700 trees/acre (836,589/ha). Elsewhere, Lotan (USDA Forest Serv. Res. Note INT69, 1967) reported that an initial negative response to thinning in 30-year-old lodgepole pine (*Pinus contorta* Dougl.) became insignificant after 11 years. Such a pattern may be applicable to jack pine and will be determined in future assessments.

Fertilization had no significant effect on height increment in either thinned or unthinned plots, but there was a trend to reduced increment in the unthinned-plus-fertilized plots. This suggests that the reaction of tree height to increased nutrition was similar to its reaction to the increased growing space that resulted from thinning.

The results indicate that diameter growth responded positively to both thinning and fertilization treatments. Lee (Can. J. Forest Res. 4:568-571, 1974) found that 25-year-old Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) responded significantly to fertilization during the first 2 years after treatment but that the effect diminished thereafter. Conversely, response due to thinning was not noticeable during the first 3 years. The results of the present study suggest that juvenile jack pine may make a more rapid response to thinning. The effect of fertilization is apparent and should become more pronounced in the later years of stand development owing to the increased number of trees in larger diameter classes. In terms of diameter-growth increase, the treatments could be ranked as follows: thinning + fertilization > thinning > fertilization > control.

Lee (1974) and DeBell et al. (Crown Zellerback Cent. Res., Camas, Wash., For. Res. Note 5, 1975) have commented on the possibility of inducing self-thinning in dense stands by stimulating dominance with fertilizer applications. Lee (1974) reported an increase in mortality beginning in the fourth year in fertilized stands. In the present study there is an indication, though not a strong trend, of greater mortality of jack pine in unthinned, fertilized plots. Such a trend may become increasingly important as the stand develops.

In the thinned stand, the diameter response (Table 2) to N at the lowest level (56 kg/ha) was not improved by the higher N levels. This suggests that the thinning itself provided sufficient increase in photosynthetic space and/or reduction in competition for available nutrients and moisture, to permit near-maximum growth. A small dosage of nutrients improved growth, but higher application rates were wasted on most trees; however, as Table 3 suggests, dominant trees may be able to capture extra nutrients.

Diameter assessments of young stands should be utilized more closely in future research as a sensitive assessment of treatment responses.—D.A. Winston, Great Lakes Forest Research Centre, Sault Ste. Marie, Ont.

Culture of Detached Branches for Controlled Pollinations in Western Hemlock.—Tree-improvement programs, in general, are dependent on the development of controlled-pollination procedures. Because of their size and remoteness, most parent or plus trees selected for breeding programs are usually vegetatively propagated and placed in breeding orchards to enable making the desired crosses.

Several years could be saved if vegetative propagation and establishment of breeding orchards, for the first phase of breeding programs, could be circumvented. One approach would be to make the crosses in the laboratory on detached branches or cuttings, which are removed from the trees after floral buds have been initiated but before the buds have opened. This approach has been commonly used for many years with several hardwood genera, e.g. *Populus, Salix, Ulmus,* and *Acer* (Johnson, For. Chron. 21:130-136, 1945), and has met with some success in two conifers, *Cryptomeria japonica* (Chiba, J. Jap. For. Soc. 34:278-281, 1952) and *Sequoia sempervirens* (Linhart and Libby, Silvae Genet. 16:168-172, 1967; Libby et al., Silvae Genet. 21:17-20, 1972). In 1975, the Pacific Forest Research Centre began testing this approach for western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in support of a newly developed tree-improvement program.

Branches bearing enlarged, but unopened, seed-cone buds were collected from three 45- to 50-year-old trees on southern Vancouver Island in late March, about 3 weeks before natural pollination would

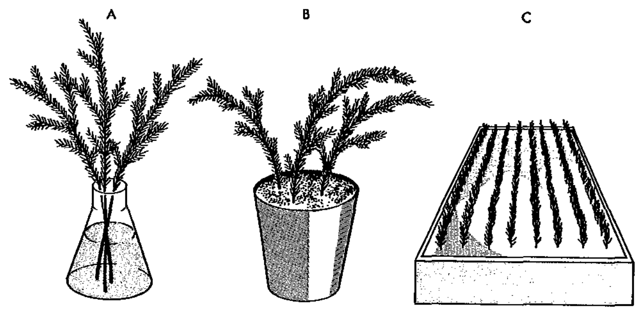

Figure 1. Treatments used to culture detached branches and cuttings. All treatments included material from all three trees. A and B treatments comprised detached branches, 50 cm in length, each branch bearing 16 seed-cone buds. Each flask or pot contained one branch per tree. C treatments comprised cuttings 6-10 cm in length, each cutting bearing a single seed-cone bud.

AQUEOUS TREATMENTS (A)

- A.1 - H_2O only, basal end of detached branch recut weekly. One detached branch per tree.
- A.2 - H_2O + IBA (5 ppm). Three detached branches per tree.
- A.3 - H_2O + IBA (5 ppm) + fertilizer solution A (FA) (Ingested, Rep. Res. Inst. Sweden 51:1-131, 1963. Control solution for pine adjusted here to 5 ppm N.) Three detached branches per tree.
- A.4 - H_2O+ IBA (5 ppm) + fertilizer solution B (FB) (van den Driessche, Can. J. Bot. 46:531-537, 1968. Standard solution adjusted here to 5 ppm N.) One detached branch per tree.

SOIL ROOTING-MIX TREATMENTS (B & C) - soil consisting of equal parts perlite, peat moss, and coarse sand.

- B.1 - soil + FA + 24-h presoak of basal end of detached branch in IBA solution. (100 ppm). Three detached branches per tree.
- B.2 - soil + FB + IBA presoak (as per B.1). One detached branch per tree.
- C.1 - soil + 24-h presoak of basal end of cuttings in IBA solution (100 ppm). Forty-eight (3 blocks of 16) cuttings per tree.
- C.2 - soil + FA + IBA presoak (as per C.1). Forty-eight (3 blocks of 16) cuttings per tree.

normally commence. Detached branches 50 cm in length and cuttings 6-10 cm in length, were placed in plywood boxes (1.2 x 0.8 x 0.6 m) covered with clear polyethylene sheeting (to maintain high humidity) within a controlled-environment room and cultured under a series of treatments (Fig. 1). Culture media were either aqueous solutions or a soil rooting-mix, with or without nutrients and IBA (3-indolebutyric acid). Treatments A.2, A.3, B.1, C.1, and C.2 were replicated three times; the remaining treatments were of lower priority and were not replicated because of space limitations in the growth room. To test the effects that pollen, or the absence of it, had on subsequent seed-cone development, half the cone buds in each treatment were designated for pollination. Growth-room conditions were seasonally adjusted to simulate normal outdoor conditions, with early-spring temperature and photoperiod settings at 13°C and 12 h, respectively, and early-summer settings at 18°C and 16-h photoperiod. Light intensity was maintained at approximately 183 lux (600 ft-c) throughout the study.

Seed cones on detached branches and cuttings were pollinated with a single-tree pollen lot during mid-April, with a fine brush. Relatively few cones (approximately 10% of the seed-cone buds) developed normally enough to permit effective pollination. While most cones continued to grow after emerging from the bud scales, there was little reflexing or opening of the ovuliferous scales, a process essential for pollen to pass to the micropyle to enable fertilization. Seed cones on the ortets (trees in the field from which branches were collected) were pollinated from late April to early May with a syringe and the same pollen lot as that used in the growth room. Cone development during and after pollination was normal on these trees.

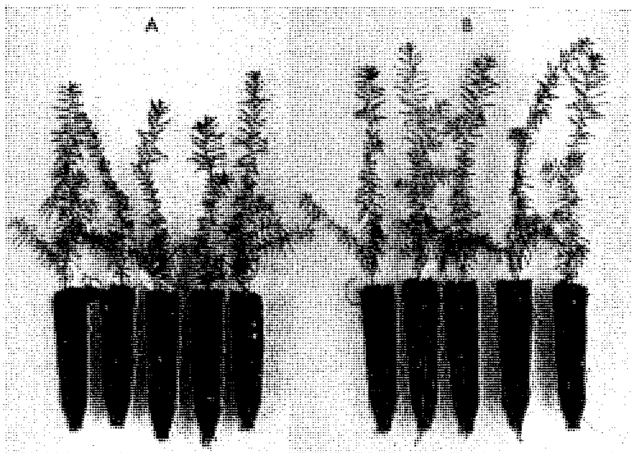

Figure 2. Representative 6-month-old seedlings from seeds produced on detached and intact branches from one of the western hemlock study trees.
A. Seedlings derived from seeds of detached-branch cultures. Mean height = 137 mm.
B. Seedlings derived from seeds of intact branches on the ortet. Mean height = 161 mm.

Cones in the rooting-mix treatments did not continue to develop beyond the initial bud-burst stage. These treatments also suffered heavy-to-total needle loss by late summer. Roots did not develop on any cuttings or detached branches in either the rooting-mix or the aqueous treatments.

In the aqueous treatments, 20% of the branches had total needle loss by late summer, and all cones on these branches became shrivelled and dry. This response, while occurring in all treatments, was more prevalent for one tree. On branches, not suffering such serious needle drop, about 75% of the cones developed to "maturity" by late summer, as judged by the brown cone color. However, the cone scales did not open normally and the cones had to be dissected to remove the seeds. Both cones and seeds averaged 50-60% the size of those produced on the ortets. There was some reduction in the total seed yields per cone, with averages of 15-25 for detached branches and 20-30 for branches left intact on the ortets. However, filled seed yields, as determined by radiography, were considerably reduced. Of the 105 cones that were pollinated and survived to maturity, 85 bore filled seeds. From these, 143 filled seeds were produced, the yield being 1.7 filled seeds per cone. For branches left intact on the ortets, the yield was 23.2 filled seeds per cone. All aqueous treatments and some detached branches of all three trees yielded some filled seeds. Treatments A.1 through A.4 yielded totals of 26, 37, 71, and 29 filled seeds, respectively. Differences in yields of filled seeds from the aqueous treatments were slight, considering that treatments A.1 and A.4 had one-third the number of potential seed cones that treatments A.2 and A.3 had at the outset.

All filled seeds were tested for germination potential, and all germinants were planted in styroblock growing containers. The numbers of germinants for treatments A.1 through A.4 were 0, 10, 34, and 21, respectively. The reduced number of germinants, as compared with filled seeds, probably reflects poorly developed embryos. The reduction was most striking in treatment A.1, none of the 26 filled seeds having germinated. While seedlings from the detached branches were initially two to three times smaller than those from intact branches, height differences decreased with age. At 6 months, average seedling heights for seeds produced on detached branches from the three trees were 85, 84, and 78% those of seedlings derived from intact branches (Fig. 2). This supports other data (Piesch, unpublished), which suggest that seed size has little effect on the growth potential of western hemlock seedlings.

While water culturing detached branches for controlled pollinations appears promising in western hemlock, much research is still needed. Further testing of the system is continuing.—R. F. Piesch, Pacific Forest Research Centre, Victoria, B.C.

MENSURATION

Metric Site Index Formulae for Major Canadian Timber Species. —Site index curves are used widely to estimate potential site productivity. In North America site index curves have been prepared for most major timber species. Construction of these site index curves has generally been based on graphical methodology; hence, to utilize them it is necessary to read and/or interpolate from a given set of curves for desired site index or height values. This is a time-consuming operation that often produces inconsistency in repeated readings for the same points.

Expressing site index curves by formulae makes possible direct computation of site index from tree height/age data, and eliminates the slow and error-prone process of reading and interpolating site index values from graphs. On large sets of data, this saves time and allows site index determination to be integrated into computerized data-processing systems.

Various mathematical equations have been fitted recently to several previously published site index curves. Using exponential growth functions Payandeh (Forest Sci. 20:143-144, 1974a; Bi-mon. Res. Notes 30:4, 1974b; For. Chron. 50:194-196, 1974c) gave equations for major Canadian timber species, expressing height as a function of site index and age (model 1) and also site index as a function of stand height and age (model 2):

$$H = b_1 S^{b_2} (1 - e^{b_3 A})^{b_4 S^{b_5}} \quad (1)$$

$$S = b_1 H^{b_2} (1 - e^{b_3 A})^{b_4 H^{b_5}} \quad (2)$$

where: H = height of dominant and codominant trees in feet
S = site index (height in feet at a base age, e.g. 50 years)
A = stand total age in years
e = base of natural logarithms
b's = constant parameters of the model

The estimated parameters for the foregoing models are valid for English units of measure only, i.e. when both stand height and site index are measured and/or estimated in feet. In computerized data-processing these estimated parameters may still be used, the resulting calculations being converted to metric units. Nevertheless, with metric conversion already in progress in Canada, and for the sake of simplicity