A comparison of cambial activity of white spruce in Alaska and New England

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White spruce trees (*Picea glauca* (Moench) Voss) producing annually the same number of tracheids had a much shorter season for cambial activity in Alaska (65° N) than in New England (43° N). We counted the number of potential dividing cells in the cambial zone (NCZ) and estimated the rate of cell division by determining the percentage of cambial zone cells in mitosis (MI) for trees of different vigor (annual tracheid production) from each region during the early summer period of relatively constant mitotic activity. Within each region, NCZ was dependent on tree vigor and MI was independent of tree vigor. Rate of tracheid production was higher in Alaskan trees because of their higher rate of cell division (higher MI).

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We have observed white spruce trees (*Picea glauca* (Moench) Voss) in Alaska comparable in age, crown class, and annual radial growth (tracheid production) to white spruce growing in New England. If the Alaskan trees have a shorter growing season, as we assumed, then they must produce cells at a higher rate. We found that Alaskan trees do indeed grow for a shorter period and produce cells at a faster rate. The two variables that could determine the rate of tracheid production are the radial number of dividing cells in the cambial zone (NCZ) and the rate at which these cells divide.[2] We found that NCZ was similar in both regions but that cells divide faster in Alaskan trees.

Cambial activity in 45- to 50-year-old trees was studied near College, Alaska (64°51′ N., 147°44′ W.), and Petersham, Massachusetts (42°31′ N., 72°05′ W.). Dominant, intermediate, and suppressed trees were sampled at frequent intervals during the growing seasons of 1964 to 1966 by removing pieces containing wood, cambial zone, and bark. From these samples, the NCZ, the percentage of cambial zone fusiform cells in mitosis or mitotic index (MI), and the radial number of tracheids produced by each year's cambial activity were determined using methods previously described by Wilson (1964, 1966). The total yearly production of tracheids per radial file was used as an index of the vigor of the tree.

In both regions, the beginning of cambial activity appeared to be related to temperature. The first mitoses were observed after 11 cumulative-growing-degree days,[3] late April in New England and late May in Alaska. Time between the first and last observed mitoses was about 95 days in Alaska and about 145 days in New England.

Two features in the seasonal pattern of cambial activity in both Alaskan and New England trees, corresponding to observations made by Wilson (1966) with *Pinus strobus*, were the build-up of the NCZ during the early season period and maintenance of this population in equilibrium with derivative production for extended periods of relatively constant mitotic activity.[4] The latter period of constant mitotic activity, when 80% of the tracheids were produced in both regions, was about 45 days in Alaska and about 95 days in New England. From samples taken during this period, we compared rate of tracheid production, MI, and NCZ between Alaskan and New England trees.

Within each region, both rate of tracheid production and NCZ were dependent upon tree

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[2]See Wilson *et al.* (1966) for terminology of cambial activity.
[3]Cumulative-growing-degree days are the sum of the amounts by which the mean temperature of each day with a mean temperature above 6 °C exceeds 6 °C.
[4]A detailed description of cambial activity in Alaskan white spruce is in preparation by R. A. Gregory.

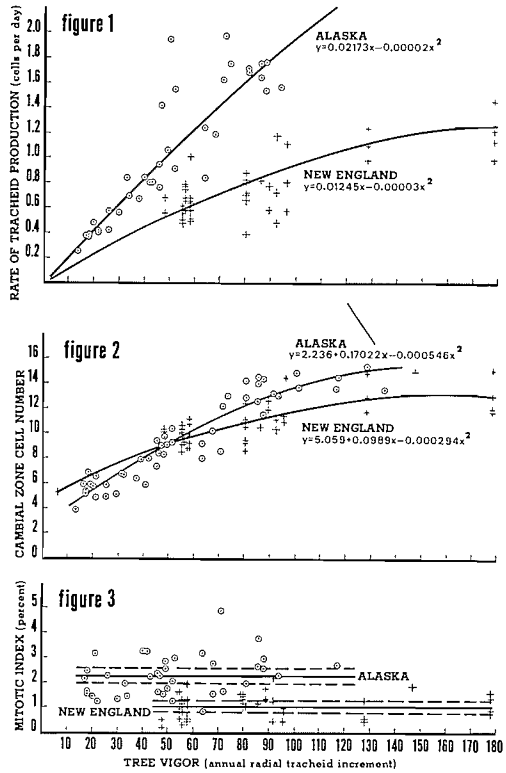

FIG. 1. Radial rate of tracheid production (cells per day) by tree vigor (annual radial tracheid increment).
FIG. 2. Radial fusiform cell number in the cambial zone by tree vigor.
FIG. 3. Mitotic index (percentage of cambial zone fusiform cells in mitosis) by tree vigor. Mean mitotic indices (solid lines) and sampling errors at the 1% level of probability (broken lines): 2.31 ± 0.32 and 1.13 ± 0.19 for Alaskan and New England trees, respectively.

vigor (Figs. 1 and 2). A second-degree polynomial equation provided the best least squares fit for these regressions, and the differences between Alaskan and New England curves were highly significant. MI, or rate of cell division, was independent of tree vigor (Fig. 3), but the difference in MI between the two regions was highly significant.[5]

Rate of tracheid production was about twice as high in Alaskan trees as in New England trees of comparable vigor. Most, if not all, of this difference was due to rate of cell division; mean MI was two times higher in Alaskan trees while, in the same period, the difference in NCZ between regions was comparatively small, ranging from zero to a maximum of two cells per radial file.

Thus, the major differences between the two regions are that the season for cambial activity is about half as long in Alaska, but the rate of cell division is about twice as fast in Alaska trees. These results suggest that Alaskan white spruce have adapted to their shorter growing season by an increased rate of cell division. Within each region, the rate of cell division is independent of the rate of tracheid production, as previously suggested for *Pinus strobus* in New England (Wilson 1964), so that rate of tracheid production is determined primarily by NCZ. In both regions, NCZ appears to reach a maximum at about 15 in white spruce (Fig. 2), thus limiting rate of tracheid production if MI does not increase. P. R. White (personal communication) has observed that tumors on white spruce trees in coastal Maine produce up to 800 cells radially per season, even though NCZ stays at about 15. He concluded that the cambial zone cells must divide once or twice every day, about 10 times faster than in normal trees of that region. If NCZ does not increase above a certain level in white spruce, then the only way to increase the rate of tracheid production at that maximum NCZ is to increase the rate of cell division. The existence of trees with different rates of division, as discussed above, suggests that increasing the rate of cell division may be amenable to silvicultural manipulation and genetic selection techniques.

[5]Analysis of covariance was used to test for differences between Alaskan and New England curves in Figs. 1 and 2, and an analysis of variance was used to test for differences in MI between the two regions. The term "highly significant" refers to significance at the probability level, $p = 0.01$.

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