INDUCED VARIATION IN THE PATTERN OF SHOOT EXTENSION IN FIVE SEED SOURCES OF PICEA ABIES (L.) KARST.

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In Norway spruce and many other species of the temperature zone, shoot extension occurs as an annual flush during a short period in spring Between flushing periods, the bud remains dormant for a large portion of the year, including a time when temperature and photoperiod are close to their natural maximum. Is this a useful adaptation or merely a relict of a former era when the favorable season was much shorter?

Can trees be induced to grow in height for a greater part of the growing season? If so, are there disadvantages to prolonging the period of height growth? If a prolonged period of height growth induced artificially produces more wood per acre per year, can we find strains or individuals with genes which bring this about under normal conditions? This investigation is a preliminary exploration of some of these questions

The experimental material consisted of five seedlots of Norway spruce. The seedlots were part of an international provenance test and were supplied by Mr. Mark Holst of the Petawawa Forest Experiment Station, Chalk River, Ontario. Three of the seedlots were from Germany, one from Poland and one from Sweden.

About 700 seedlings in all were subjected to a 20-hour photoperiod and summer temperatures in a greenhouse on various dates and for various times during a three-year-period. At the beginning of the experiment the trees had completed their second growing season and were transplanted into pots to permit moving in and out of the greenhouse. Extension of the main axis was measured to the nearest millimeter at weekly intervals. The data were plotted and the duration of growth was read from the curves.

In spruce, as in many tree species, extension growth during one growing season Is an expansion of an embryonic shoot on which all leaf initials were formed during the preceding growing season. Ordinarily, when the new shoot has completed its expansion, no further extension growth takes place until the bud has been chilled.. However, as a result of the treatment, this normal or first flush of growth was often followed by a second flush which developed from the unchilled bud whose leaf initials expanded soon after they were laid down.

The figures show some features of first and second flushes. In most cases it was easy to recognize the end of the first flush and the beginning of the second flush - both on the plant and on the growth curve.

Figure 1

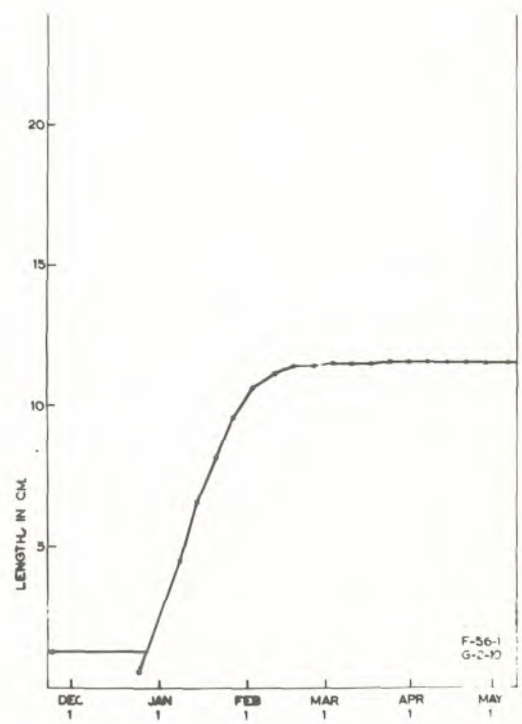

Figure 2

Figure 1 shows a normal annual flush. The year's growth began at the point between the uppermost lateral branches. Note at the tip the cluster of needles at an acute angle to the stem and surrounding the bud. Figure 2 is the growth curve of the same annual shoot. The plant was brought into the greenhouse in late November; bud-break occurred about a month later; growth proceeded rapidly for about six weeks and stopped rather abruptly.

Figure 3

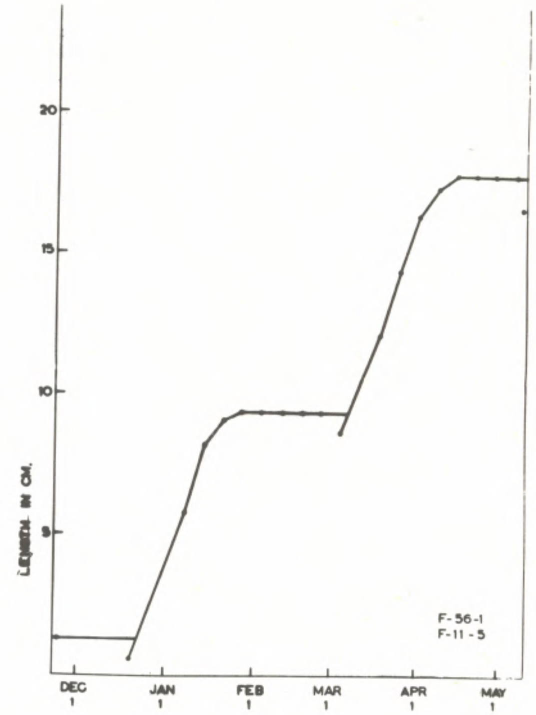

Figure 4

Figure 3 shows a tree with two flushes of growth. A cluster of needles set at an acute angle to the stem marked the end of the first flush; the position of last year's bud was between the two uppermost lateral twigs. There is a difference between flushes with regard to texture and abundance of needles. Figure 4 shows the growth curve of the two flushes. The first flush ended with a rest period.

In other trees, the beginning of the second flush was not so easy to recognize. In Figure 5 is an example of where its position was marked by the new twigs and the bud-scales which do not show in the figure. The terminal needle cluster was absent and there was little difference in the needles on the two flushes. Figure 6 shows the growth curve. Here again the position of the end of the first flush was indefinite. There was no rest period, only a slowing of the growth rate.

A vigorous second flush is often characterized by non-dormant buds as shown by one of the plants in Figure 7. The plant on the left shows the condition of a normal single flush - the buds remain dormant until the next growing season. In the tree with two flushes, the buds on the second flush began to elongate almost as soon as they were formed. The mechanism which maintains dormancy was not operating normally. The lateral buds on the first flush were still dormant except those at the apex which extended at the same time as the terminal bud. The result is a spruce internode with an abnormal form. Ordinarily the branches of an internode are shorter towards the base as shown on the right specimen. With a vigorous second flush the reverse is true.

Figure 5.--A Norway spruce seedling with two flushes of growth. The position of last year's bud was opposite the "3" on the label. The end of the first flush is not well marked.

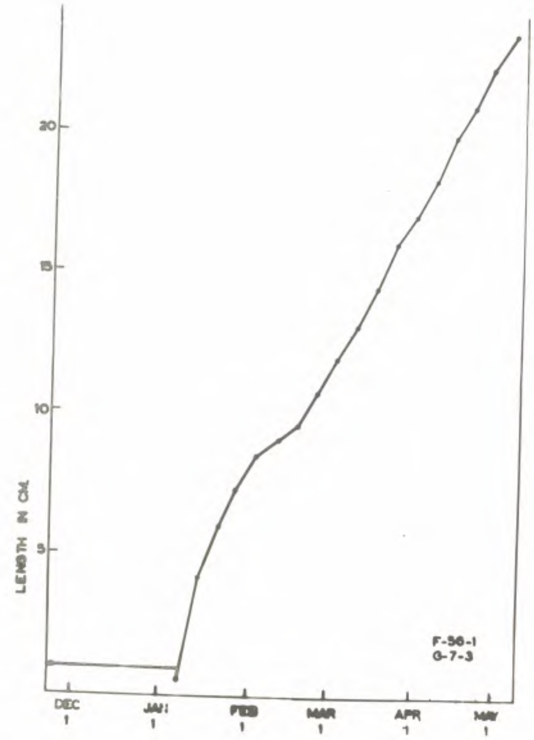

Figure 6.--The curve of height growth for the seedling shown in Figure 5. The end of the first flush is marked by a slowing of the growth rate in February.

Figure 7.--A seedling with normal flushes of growth (left), and one with two flushes in one year (right), each of which is about 15 cm. long. (The black lines are 10 cm. apart). Note the new twigs on the second flush of growth: the longest is toward the base in contrast to the normal seedling where the longest twigs on a "node" are at the apex.

Figure 8 shows how the period in the greenhouse affected the duration of the two flushing periods. For example, for those brought in on November 23, growth resumed 44 days later. The first flush expanded during the next 47 days. There was a rest period of 12 days, and subsequent growth lasted for 82 days. The controls remained outside all winter. Growth began on May 5 and lasted for 43 days. There was only the one flush of growth. The interval between exposure to greenhouse conditions and bud break got progressively shorter. The period required for the expansion of the first flush was not affected by the duration of treatment; it lasted for 6 to 7 weeks. The rest period after the first flush was irregular and probably not affected by the time of treatment.

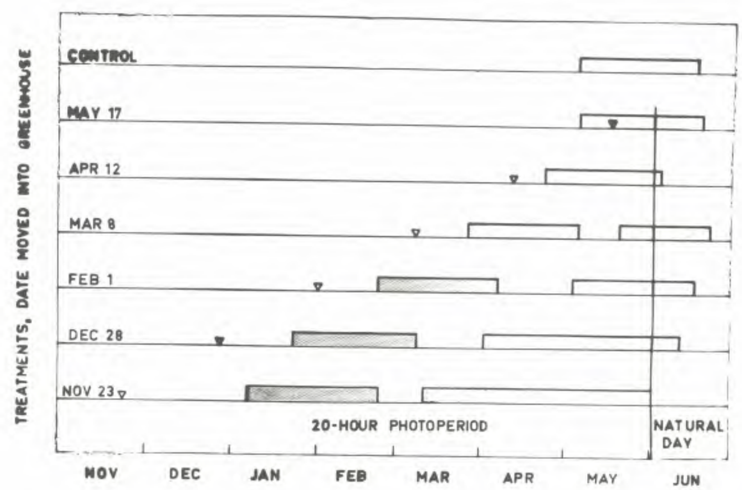

Figure 8.--The periods of growth and rest of the seedlings. Each horizontal line is devoted to a group of plants brought into the greenhouse on the day indicated by the small triangle. The growing periods are outlined. The plants were returned to natural outdoor conditions on June 2.

The duration of the second flush was related to the duration of the greenhouse treatment. All plants were removed outdoors on June 2, and soon after that date shoot extension ceased. However, many of the November group, with a second flush, had ceased to extend while still in the greenhouse. And where extension growth was in progress, it continued longer if it had only recently started - some continued to extend for as long as 35 days after being removed from the greenhouse.

Only plants, which were exposed to greenhouse conditions for ten days or more after completing the first flush, produced a second flush. However, there was a considerable lag after the induction period, since a second flush was initiated as long as ten days after removal from the greenhouse.

The experiment was not designed to show which feature of the greenhouse climate induced the second flush of growth. The 20-hour day was probably the key feature. Of course warm temperature is necessary, but that alone usually results in only one flush of growth. The effect of the duration of the treatment in prolonging the growing period is brought out in Figure 9 which shows some of the previous data in a different form. The amount of growth in a flush was proportional to its duration, so length of shoot is also indicated.

The first flush - the normal growth - is relatively unaffected by treatment. In contrast, the second flush is initiated by treatment, and its duration is partly controlled by duration of treatment.

Figure 10 shows the date of bud-break in relation to the date on which the plants were brought into the greenhouse. Three years' observation are combined, including some data already shown. Those brought into the greenhouse about the time of bud-set resumed growth fairly soon. Those brought in during the summer did not resume growth until mid-winter. Those brought in after the onset of cool weather flushed progressively later. However., the duration of the period spent in the greenhouse before flushing became progressively less and reached zero in May.

These results can be interpreted as follows. Immediately after bud-set, dormancy is relatively mild and can be broken by a long photoperiod. These seedlings were in much the same condition as those which flushed in the greenhouse. They produced two flushes of growth in one growing season.

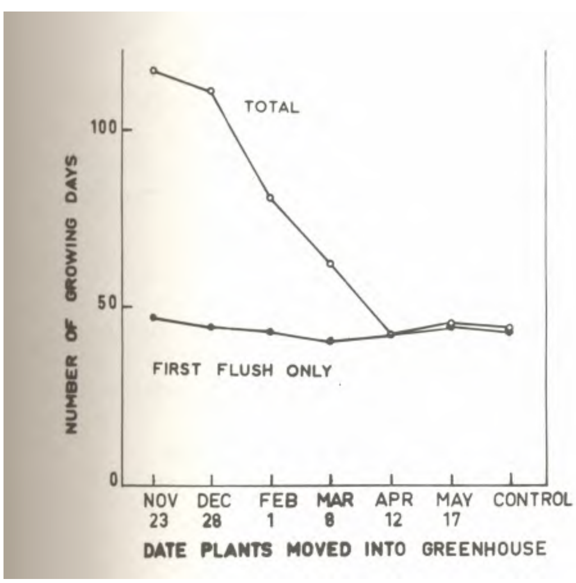

Figure 9. --The length of the growing period for the first flush and for all growth in relation to the date on which the plants were brought into the greenhouse.

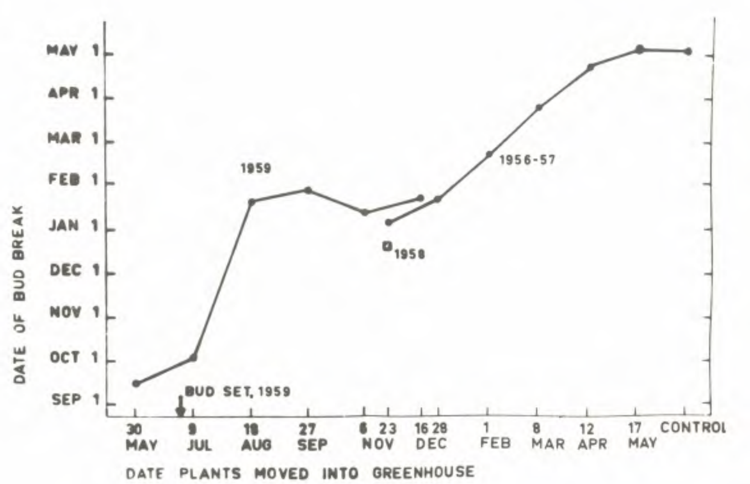

Figure 10. --The date of bud-break in relation to the date the plants were moved into the greenhouse. Data from three experiments were combined.

As the season progresses, dormancy deepens. was sufficiently intense that it reqt. red five months of greenhouse conditions to break dormancy. Probably a more significant parameter, in place of time in the greenhouse, would be te time that had elapsed since bud-set. In these terms, it required almost seven months of summer weather to break dormancy. This was without chilling.

Sometime in November the effect of chilling became apparent, and from then on the necessary period in the greenhouse became shorter and shorter. At first this indicated an increasing fulfillment of the chilling requirement, but as spring approached the shortened period indicated that the plants requirement for warmth was partially being met out of doors.

Holst (1956) found that Norway spruce, which had been exposed to normal chilling and brought in in November, broke dormancy several weeks ahead of those which were not chilled. The same seems to have occurred in these experiments. Of course, it depends on how soon the coldweather arrives.With an early autumn, the effect would be greater.

The deepening of bud dormancy during the warm weather following bud-set has been discussed by Doorenbos (1953) and Wareing (1956) in terms of the requirements for breaking dormancy. It is evident that the changes in the bud also include a change in the nature of the twig which develops from it. Twigs from winter-dormant buds were usually limited in growth potential and bore dormant buds. Twigs from summer dormant buds were often capable of indeterminate growth under suitable environment and bore accessory branches.

There were no consistent differences between seed sources. However, there was much variation between individual seedlings within a seed source. Curiously, when seedlings were subjected a second time to long days and summer temperatures in midwinter, there was no consistency with regard to the occurrence of a second flush. Those which had produced a second flush at the first treatment were neither more or less likely to produce a second flush after the second treatment. This suggests that the occurrence of a second flush is partly controlled by an internal non-genetic feature such as the seedling's condition of health Further investigations seem warranted.

Literature Cited

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