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THE ACCURACY OF MEAN-GROWTH ESTIMATES MADE WITH DIAL-GAGE DENDROMETERS

In recent years a great deal of interest has been focused on tree growth as measured with relatively precise instruments over short periods of time. These growth measurements are usually made with vernier-band dendrometers similar to those described by Hall (1944) and Liming (1957), or dial-gage dendrometers similar to those described by Reineke (1932) and Daubenmire (1945).

Most of the dial-gage dendrometers measure growth in more precise units than the vernier-band dendrometers; but unlike the vernier-band type, they measure increment at only one of an infinite number of radii at a given height on a tree bole. The vernier-band dendrometers, on the other hand, measure circumferential growth, which may be converted to mean diameter growth. This measurement includes the increment accrued at all of the infinite number of radii at the cross section of the bole being measured.

For some work, the greater precision and sensitivity to both positive and negative changes in increment make the dial-gage dendrometer more desirable than the vernier-band type. However, it is generally known that growth may vary among the radii at a given height on the bole of a tree; and a number of investigators have cautioned that estimating mean growth from only one or two radial measurements may be misleading (Reineke 1948; Young 1952; Bormann and Kozlowski 1962).

Therefore a study of radial-growth variation and the accuracy of mean-growth estimates derived from as many as six radial measurements per tree was made during the summer of 1964 at the Bartlett Experimental Forest in New Hampshire. The species studied were yellow birch (*Betula alleghaniensis* Britton), paper birch (*Betula papyrifera* Marsh.), and sugar maple (*Acer saccharum* Marsh.).

Methods

Radial growth was measured on a sample of six trees each of the three species and within two size classes: small trees (2.0 to 4.0 inches d.b.h.) and intermediate trees (8.0 to 12.0 inches d.b.h.). Six dial-gage dendrometer stations were placed randomly on each of the 36 individual trees. (Randomization was accomplished by spinning a pinwheel divided into 36 ten-degree segments.) Growth measurements were made weekly at each station, using a two-point dial-gage dendrometer adapted (Blum 1965) for use on the smaller saplings as well as on the larger trees (fig. 1). Individual sample trees were selected for similar phyical characteristics and for similar growing conditions.

The data analysis was based on the seasonal radial growth at each measurement point. The first step was to compute the variance among the six growth measurements on each tree. The variance of the six trees within each species and size group were then tested for homogeneity.[1] Differences in the variances of yellow birch in both size classes were large enough to attain significance at the 5-percent level, but none of the differences in variances was significant at the 1-percent level. Although the assumption may be questioned for yellow birch, all variances within each group were considered homogeneous in order to permit comparable results. The variances were then pooled to obtain a single estimate for each species and size group, and the pooled variances were used to calculate the 95-percent confidence intervals for mean-growth estimates based on two, three, four, five, and six radial measurements.

[1] Homogeneity of variance was tested by using procedures outlined by Walker and Lev (1953) for testing the homogeneity of two or more samples with the same number of observations.

Figure 1.—Measuring growth of a yellow birch sapling with a two-point dial-gage dendrometer.

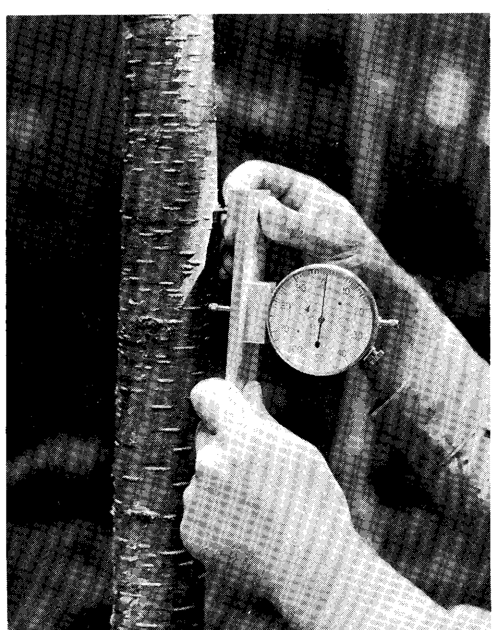

Table 1. — **Width of confidence intervals, in inches and percent of overall mean, for mean-growth estimates derived from randomly selected radial-growth estimates**[1]

(Basis: 6 dendrometer measurements per tree, 1964 season)

Species	Mean radial growth	2 stations		3 stations		4 stations		5 stations		6 stations	
	Inches	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*	*Inches*	*Percent*
SMALL TREES											
Yellow birch	0.1563	±0.0303	±19	±0.0243	±16	±0.0208	±13	±0.0183	±12	±0.0164	±11
Paper birch	.1532	± .0358	±23	± .0288	±19	± .0246	±16	± .0216	±14	± .0194	±13
Sugar maple	.0835	± .0153	±18	± .0123	±15	± .0104	±13	± .0092	±11	± .0083	±10
INTERMEDIATE TREES											
Yellow birch	.0640	± .0225	±35	± .0181	±28	± .0154	±24	± .0136	±21	± .0122	±19
Paper birch	.0761	± .0218	±29	± .0175	±23	± .0149	±19	± .0132	±17	± .0118	±15
Sugar maple	.0733	± .0132	±18	± .0106	±15	± .0094	±13	± .0080	±11	± .0072	±10

[1] The computation of the confidence intervals was made according to the following:

$$\frac{\pm\ t(.05,\ 30)\ (s)}{\sqrt{n}} \quad \left(\sqrt{\frac{N-n}{N-1}}\right)$$

Where N = Number of items in population = 36.
n = Number of radial measurements = 2, 3, 4, 5, or 6.

Results and Discussion

The confidence intervals for the trees studied ranged from ± 18 percent to ± 35 percent of the mean growth for two stations per tree to ± 10 percent and ± 19 percent of the mean growth for six stations per tree (table 1). Of course, a higher degree of accuracy is achieved as the number of stations is increased. As a general recommendation, four measurement points would seem to provide a useful compromise between accuracy and practicality. However, even with four points dial-gage dendrometer users should be aware that the true mean growth may deviate 13 to 24 percent from the estimates.

In some dendrometer studies, great accuracy in estimating mean growth is not required. In a study aimed at determining seasonal patterns of growth, for example, the relative fluctuations may be more important than the actual amount of growth. But even in these studies, differences in growth at various radii must be considered to obtain an accurate estimate of the fluctuations.

These results further document the fact that variations exist in the growth of individual trees. Instruments that measure growth at only one radius are therefore at a disadvantage in estimating mean growth, but the extreme sensitivity of dial-gage dendrometers make them especially desirable for many studies. Information presented here provides a guide to the magnitude of variation that might be expected in similar samples, and an approximation of the number of growth measurements needed to obtain a workable degree of accuracy. This information should be especially helpful in the planning of future dendrometer studies.

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