ANNUAL-RING WIDTH AND DENSITY PATTERNS IN RED ALDER[1]

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ABSTRACT

X-ray densitometry was used to measure ring width and ring density in eight red alder (*Alnus rubra* Bong.) trees from British Columbia. Mean, minimum, and maximum ring density were studied in detail and summary intra-ring density profiles were produced. Generally there is a negative trend in ring width from pith to bark. There is no trend in specific gravity that is both strong and consistent. False annual rings and faint and microscopic rings make the definition of ring boundaries difficult and may lead to incorrect estimates of tree age.

Keywords: *Alnus rubra* Bong., X-ray densitometry, red alder, ring width, density patterns.

INTRODUCTION

Annual-ring studies are being conducted by the Western Forest Products Laboratory using the technique of X-ray densitometry (Parker and Kennedy 1973), and also by the University of British Columbia (U.B.C.), Faculty of Forestry, using a Swedish ring-width-measuring instrument (Eklund 1949). This research is being done for a number of purposes, including studies in dendrochronology, growth and yield, environmental effects, and wood quality. The methods used for a particular study are determined to some extent by the purpose of that work; the quality of the data produced is determined in part by the nature of the species being examined.

Annual-ring studies of red alder (*Alnus rubra* Bong.) could be of value because they record age and the effects of many other factors causing natural variation in tree growth and stand yield. In addition, effects of various stand treatments can be estimated by study of tree rings at breast height. Stem analyses of whole trees are made to determine growth in height, diameter, and volume, assuming that increments are well defined annually. If age is not correctly determined, all subsequent analyses depending on age will be in error. Tessier and Smith (1961) drew attention to the lack of conformance of ages of a stand of red alder on the U.B.C. Research Forest near Haney, B.C., with the known date of disturbance and to the wide variation in ages at the stump. Smith (1974), after studying similar nearby trees, attributed the apparently low age of these red alders to missing rings at the stump.

The purpose of this paper is to present in detail, for a few red alder trees, annual-ring width and density* trends from pith to bark, and to show the nature

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* The unit of measure is g/cm^3, oven-dry volume and oven-dry weight. Ring width measurements are made on the samples in an air-dry condition. Calibration techniques used to obtain the oven-dry condition values are described by Parker et al. (1977).

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TABLE 1. *Sample tree statistics.*

Tree[1]	Sample level	Estimated age at sample level (yrs)	Sample diameter outside bark (cm)	Mean ring width (mm)	Mean ring density (g/cm³)
1	Stump	6	9.6	7.58	0.3417
2	Stump	7	12.5	8.00	0.4239
3	bh	17	11.6	3.22	0.3926
4	bh	19	17.0	4.06	0.4492
5	bh	21	18.8	4.18	0.4389
6	bh	25	12.4	2.16	0.4497
7	bh	45	20.4	2.27	0.5174
8	Stump	78	33.0	1.98	0.3642

[1] Stump height disks were used from two U.B.C. Endowment Land trees (1 and 2) and the U.B.C. Research Forest Tree (8); trees 3–7 were from the U.B.C. Endowment Lands as represented by breast-height cores.
bh = breast height.

of the red alder intra-ring density profile. In conducting this study, problems were encountered in determining the location of annual-ring boundaries. Therefore, this paper also endeavors to illustrate some cases where it is difficult to discern the ring boundaries, to show the quality of crossdating between trees, and to consider some aspects of the feasibility of conducting annual-ring studies on red alder for various purposes.

MATERIALS AND METHODS

An extensive study of ring widths of red alder, using an ADDO-X ring-width measuring machine, is being conducted by the U.B.C. Faculty of Forestry. The present study utilizes a few samples selected from the larger collection of this more extensive study. Ten breast-height increment cores from 10 different red alder trees were selected to represent the variation in ring widths among 107 trees growing on the U.B.C. Endowment Lands in Vancouver, B.C. In addition stump, breast height, mid-bole and top disks from a 100-year-old red alder tree cut from the U.B.C. Research Forest, and disks cut at deciles of height from two 10-year-old trees from the U.B.C. Endowment Lands, were submitted to the Western Forest Products Laboratory for X-ray densitometric analysis. From these cores and disks the trees in Table 1 were chosen for analysis. Radiographs were made of the cores using a technique described previously (Parker and Jozsa 1973). The disks were sanded with a belt sander, using a number of grits from heavy to fine, for examination under a low-power binocular microscope. Radiographs also were made of a pith-to-bark sample taken from each of the breast-height disks.

Five of the Endowment Lands increment cores, with the most well-defined ring boundaries, were selected for the construction of the intra-ring density profiles. Radiographs of these five cores and of the samples taken from the Research Forest disks were processed on a computerized scanning densitometer (Parker et al. 1973) and the data were stored on magnetic tape in a format described by Parker et al. (1974). The parameters considered for this study are: (1) ring width, (2) mean ring density, (3) maximum ring density, (4) minimum ring density, and (5) the intra-ring density profile, consisting of 100 density values for each ring.

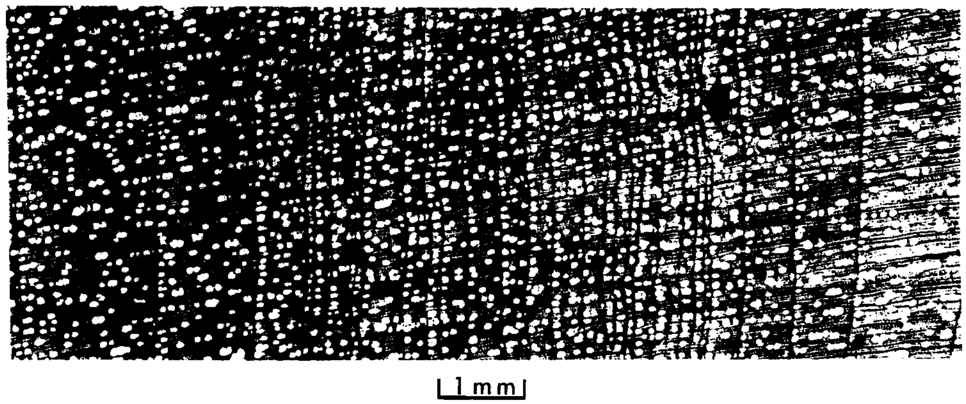

FIG. 1. A microtome cross section reveals the faint nature of annual rings in an area of reduced red alder growth. The arrow points to a region where an annual ring is locally absent.

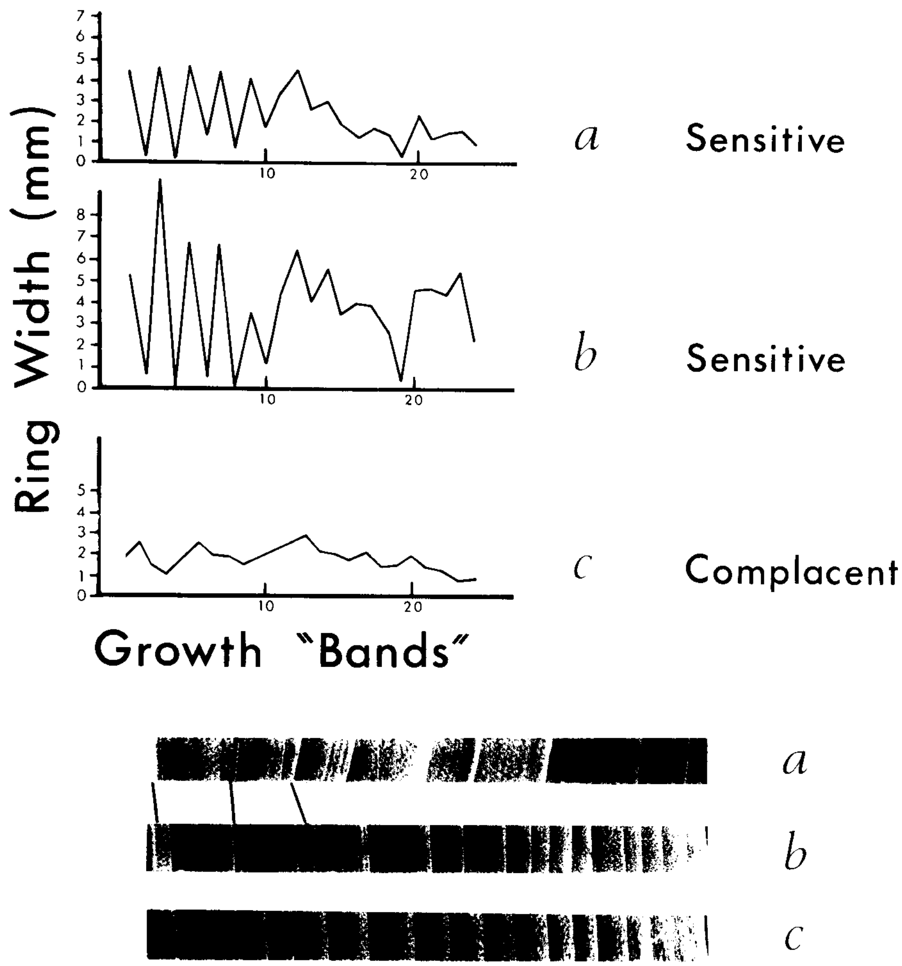

FIG. 2. Comparison of crossdating between sensitive and complacent red alder cores. The ring "bands" of the two sensitive cores (*a* and *b*) crossdate with one another, but not with the rings of the complacent core (*c*).

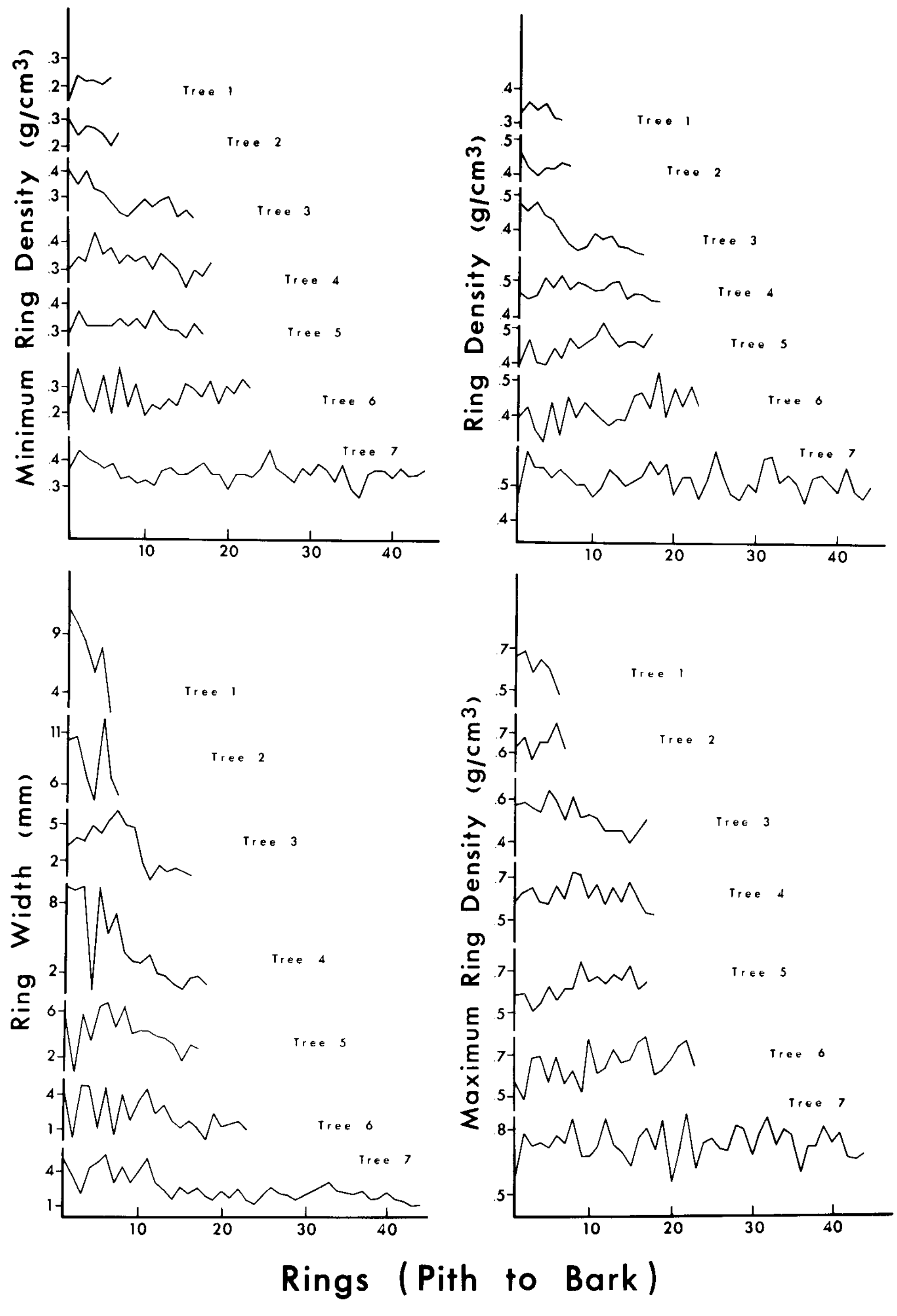

FIG. 3. Broken-line plots of ring width and ring density variables of seven red alder trees from the U.B.C. Endowment Lands, showing the presence or absence of trends from pith to bark.

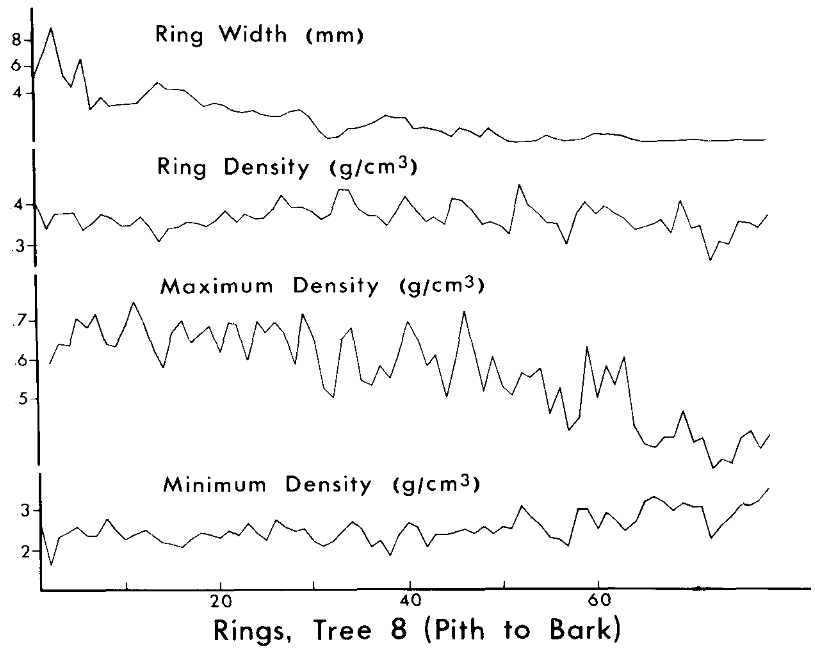

FIG. 4. Broken-line plots of ring width and ring density variables of a red alder tree from the U.B.C. Research Forest, showing the presence or absence of trends from pith to bark.

DEFINING RING BOUNDARIES

The growth rings in red alder have been defined as "distinct" (Panshin et al. 1964; Overholser 1968), but we found that many ring boundaries were far from distinct on a number of samples used in this study. This observation was confirmed for us by Dr. John Worrall for a sample of red alder growing in the U.B.C. Research Forest, for which the number of rings did not correspond to the known age. For most annual rings used in this study, there is a very distinct band of dense fibers, 0.05 to 0.15 mm wide, at the termination of the ring that sets one ring off from the following ring; but in some cases the ring boundaries are very faint and indistinct, especially in areas on the samples of very reduced growth.

False rings are sometimes present that easily could be mistaken for true annual rings. One core apparently had four false rings in its 23 years of growth, since the site was disturbed.

The sanding technique used to put a smooth surface on the red alder disks is adequate for producing a good quality surface on a coniferous species, such as Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], for examination under a low-power binocular microscope. This technique, however, did not produce a surface on the red alder disks that showed distinct ring boundaries in all cases. This suggests that errors easily could be made in the assignment of calendar-year dates to annual rings.

To examine the annual rings in more detail, microtome cross sections were made of a sample taken from a slow-growth area on the disk from the Research Forest (Fig. 1). Generally, double rings (false annual rings) are not present in the

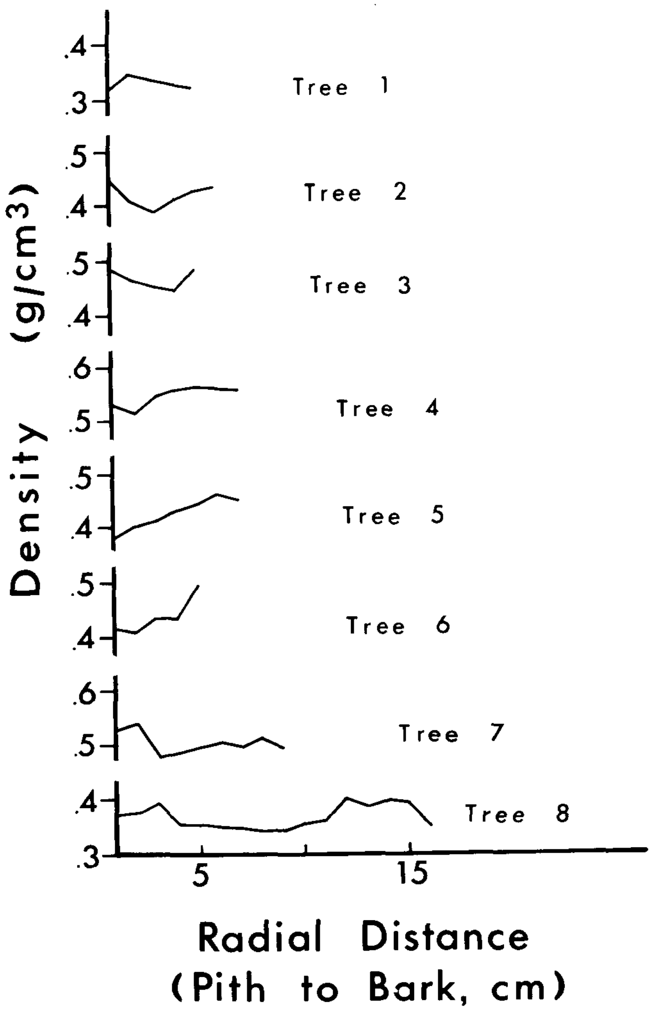

FIG. 5. Density trends in eight red alder trees measured at 1-cm intervals.

narrow rings of slow growth. Therefore, the "rings" that can be seen, no matter how faint, are in almost all instances true annual rings. The fact that some rings were observed to "wedge out" (Schulman 1940), or become locally absent (Fig. 1) suggests that some rings may be completely absent from the sample being studied. This leads to errors in estimating tree age from ring counts.

CROSSDATING

"Crossdating," or the matching of one tree-ring series with another, is one of the most basic principles of dendrochronology. This technique can be used not only to date wood samples of unknown age, but also to determine whether a questionable ring is a true annual ring or a double ring. Also, if crossdating is present between two tree-ring series, this is an indication that these trees are responding to some common environmental factor such as climate.

An effort was made to crossdate the ring series of the increment cores taken from the Endowment Lands red alder trees. Although the trees were collected at the same time and were of about the same age, the difficulty in crossdating led to the conclusion that in some cases crossdating does not exist, either for the ring width or ring density variables; however, in other cases good crossdating is present. To illustrate this, two sensitive (marked year-to-year variation in ring width and density) (Stokes and Smiley 1968) increment cores were compared with one another and with a complacent (little year-to-year variation) core (Fig. 2). There is very good crossdating between the two "sensitive" cores for ring width and the presence or absence of false-ring bands. The "complacent" core, although it comes from the same area and represents the same growth period, shows no crossdating with the other two cores. It also can be noted that, although a good visual comparison can be made between the two sensitive cores, the ring bands are not distinct enough to allow one to visually determine whether they are true annual rings or false rings.

RING WIDTH AND RING DENSITY TRENDS

Annual-ring width and density are useful statistics in determining growth and yield of trees. Four parameters—ring width, mean ring density, minimum density, and maximum density—were examined in detail for five increment cores from the U.B.C. Endowment Lands and for samples taken from three disks, one from the U.B.C. Research Forest and two from the Endowment Lands (Figs. 3 and 4). This was done by taking specific gravity measurements at 0.01-mm intervals using the technique of X-ray densitometry. To process this material, "questionable" or "problematical" ring boundaries were marked on the radiographs, but no calendar-year dates were indicated because these dates could not be assigned with certainty. Figure 3 shows a comparison of seven trees for each of the four variables, and Fig. 4 compares the four variables for a single tree.

Density trends were examined in another manner, independent of the annual rings, by using X-ray densitometry to measure specific gravity at 1-cm intervals from pith to bark (Fig. 5); i.e., Figs. 3 and 4 show the pith-to-bark density trend by rings, and Fig. 5 shows this trend by equally spaced intervals. The differences in these plots result from the fact that the annual rings vary in width from pith to bark.

In general, there is a reduction in ring width (negative growth trend) from pith to bark. (This also was found to be the case for increment cores measured on the ADDO-X in the more extensive study mentioned above.)

There are no strong and *consistent* trends of reduced or increased density for any of the three variables measured—ring density, minimum density, or maximum density. Some cores show a negative trend, but there are some that have a positive trend and some with essentially no trend. This lack of a strong and consistent positive or negative trend holds true whether the cores are examined by distance (Fig. 5) or by ring (Figs. 3 and 4).

INTRA-RING DENSITY PROFILES

Radiation densitometry makes possible the rapid and accurate measurement of the intra-ring density profile. The value of the intra-ring density profile for wood quality studies has been recognized to some extent (Echols 1971, 1973), but has

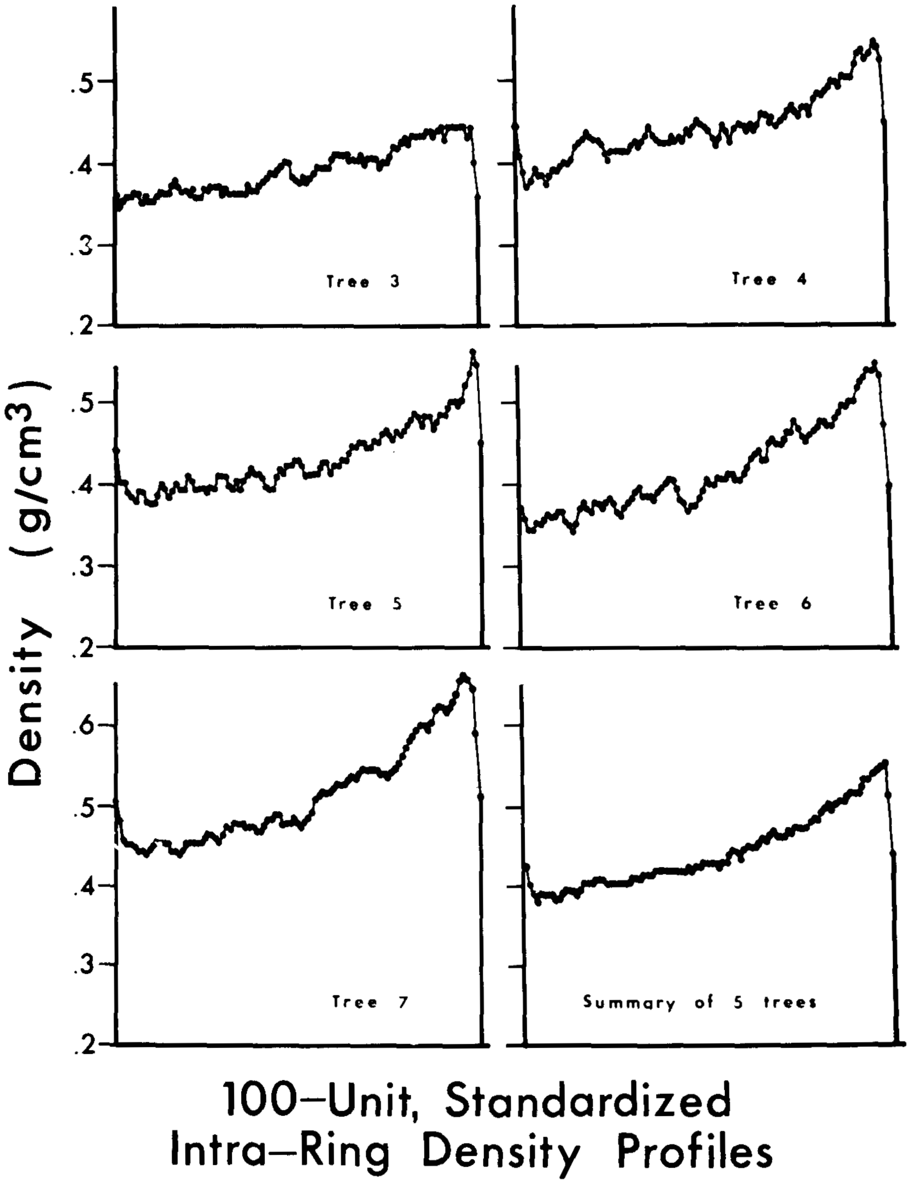

FIG. 6. Intra-ring density profiles. Tree 3, summary of 16 rings; Tree 4, 18 rings; Tree 5, 17 rings; Tree 6, 23 rings; Tree 7, 44 rings. The mean profile of the five trees is a summary of 118 rings.

not been extensively utilized. It can be expected, however, that after more data have been produced for this feature, it can be used for evaluating strength, turning, planing, and other related properties of wood.

Intra-ring density profiles were produced for each annual ring (or "questionable" ring) on the five cores selected form the Endowment Lands trees. Density measurements were taken at 0.01-mm intervals across the rings and these values

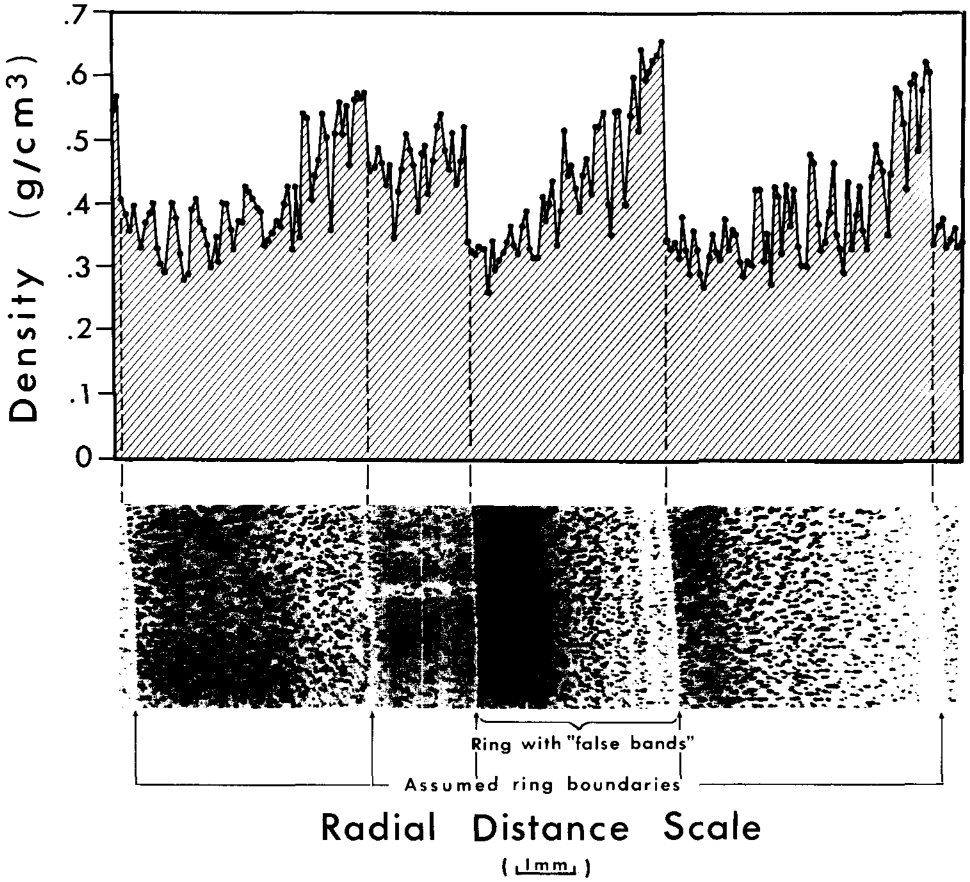

FIG. 7. Intra-ring density profiles of four rings of Tree 6.

were standardized by converting each ring profile to 100 units. These 100-unit profiles were then summarized together to produce a summary profile for each core, and all of the core summary profiles were averaged to produce a summary profile of the five cores together (Fig. 6). There may have been some errors made in the assignment of the ring boundaries. But the five-core summary profile includes the profiles of 118 rings and it should be a fairly accurate representation of the summary intra-ring density profile of the five trees as a whole at the breast height level.

The large voids of the vessels present in the transverse section of red alder wood (or hardwoods in general) lead to extreme density variation in the density profile produced by a single scan (Fig. 7). This problem was pointed out by Polge (1971) and he demonstrated that it can be minimized by producing the radiograph with an X-ray beam that penetrates a radial section of wood in a tangential direction. However, if the ring boundaries are skewed, as they generally are, a blurry radiograph will be produced by X-raying a radial section of wood. If the intra-ring density profiles in Fig. 6 are compared with the profiles in Fig. 7, it can be noted that the variation in the individual-ring profile is smoothed when a number of individual rings have been averaged together to produce the summary profile.

This extreme density variation in the individual-ring profile (Fig. 7) required a variation in the normal densitometer scanning technique. The ring boundaries for the red alder in this study were "triggered" manually by an operator, rather than being triggered automatically by the data-acquistion system at predetermined density levels (Parker et al. 1974).

DISCUSSION AND CONCLUSIONS

Data derived from the few trees examined in this study indicate that in most cases there is a negative trend in ring width (rings get narrower from pith to bark), but there is no strong and *consistent* trend, positive or negative, for mean ring density.

Information about the shape of the intra-ring density profile will be of more value in the future, as more profiles have been determined for other red alder stands and for trees of other species and, also, when comparisons are made between these profile configurations and other wood properties.

In many cases, it is difficult to determine with certainty whether apparent rings on the red alder samples are false rings or true annual rings. Unless the annual rings have been properly dated, i.e., assigned the correct calendar-year date, the ring series cannot be used for climatic studies or tree-ring dating. If the red alder samples are to used for growth and yield studies, the ring boundaries must be distinct enough that a fairly accurate ring count can be made. If they contain confusing false rings, however, the age of the tree may be overestimated. If samples contain very narrow rings, such as those shown in Fig. 1, the age of the tree may be greatly underestimated. Correct dating is less critical in the construction of summary intra-ring density profiles that represent the average of a large number of rings.

This report is based on data from only a few trees and must be considered somewhat tentative. More research is needed on a large number of red alder trees of known age, *if* the nature of the ring boundaries is to be better understood and *if* red alder tree-ring series are to be compared with climatic factors or are to be used for other studies that require accurately dated samples. Red alder is relatively short lived and is of poor quality for climatic studies, when compared with an associated species, such as Douglas-fir. Therefore, more fruitful results would be obtained from using species other than red alder for climatic studies. For growth and yield studies, a good method would be to measure diameter growth of trees from stands of known age, such as those in previously logged areas. If certain studies must depend on ring counts of red alder, the limitations of this method must be taken into consideration.

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