INTRACLONAL VARIATION IN WOOD DENSITY OF TREMBLING ASPEN IN ALBERTA[1]

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ABSTRACT

Four trees from each of three putative clones of trembling aspen (*Populus tremuloides* Michx.) at one site in north-central Alberta were sampled to determine the patterns of wood density variation within stems and within clones. Sample disks were removed at five heights from each tree to examine variation among cardinal directions and across the southern radius at each height. Although only three clones were sampled, there were significant differences (0.05 level) among clones. Wood density tends to be high at the bottom of the tree, decreases to a minimum at midheight, then increases again near the top of the tree. In the radial direction, wood density is high near the pith (at all heights), decreases, then increases again in the mature wood zone (after rings 15–20+). Average wood density values within the twelve stems varied from 0.348 g/cc to 0.402 g/cc.

Keywords: Wood density, *Populus tremuloides* Michx., intraclonal variation, specific gravity.

Wood density (or specific gravity) is the most important factor affecting wood quality (Zobel 1961). Considerable differences in wood density exist among both individual trees and forest stands (e.g., Farmer and Wilcox 1966; Posey et al. 1969; Walters and Bruckmann 1965). Before among-tree variation can be accurately assessed, however, patterns of within-tree variation must be known, especially in young trees with large proportions of juvenile wood.

Over the past few decades, trembling aspen (*Populus tremuloides* Michx.) has become economically important in parts of North America. With the increased use of aspen, primarily as a source of fiber for pulp and paper, interest pertaining to its wood or fiber quality, utilization, and growth also has increased (Maini and Cayford 1968; Einspahr 1972).

Aspen typically occurs in stands consisting of a mozaic of clones, each clone composed of many genetically identical ramets (Barnes 1966). A number of studies have dealt with interclonal variation of wood density in trembling aspen (Brown and Valentine 1963; Einspahr and Benson 1967; Einspahr et al. 1963; Van Buijtenen et al. 1959; Valentine 1962), but little information is available on the variation of this property within trees. The purpose of this paper is to report on patterns of wood density variation within aspen trees at one site in north-central Alberta.

MATERIALS AND METHODS

The sample area was located approximately five miles north of Blue Ridge in north-central Alberta (SE¼, Sec. 10, TP60, R10, W5th). Three adjacent clones were delineated on the basis of phenotypic and phenological differences as described by Barnes (1969). Four stems from each of three clones were selected for study. Five 6-cm thick disks were removed from each tree at progressive heights of 0.6, 3.0, 5.5, 7.9, and 10.4 m above ground (approximately 2.4 m intervals). The twelve stems sampled varied from 40 to 47 years of age. All trees sampled had straight, nonleaning stems without advanced or incipient decay. Four 10-degree wedges were removed from the north, south, east, and west cardinal directions of each disk. Wood density of all 240 wedges was calculated on an oven-dry/green volume basis. Green volumes were obtained by soaking the trimmed wedges for 24 h in water, removing excess moisture from the surface of the samples with a damp cloth, and weighing each sample by water displacement (measured to 0.001 g), which gave green volume in cubic centimeters. Oven-dry weights were obtained by drying the samples for 24 h at 103 C, and recording dry weights to the nearest 0.0001 g after the samples had cooled to room temperature. After wood density determination, wedges removed from the southern cardinal direction were used for further analysis. These sixty wedges were divided into five-year sections from the pith outwards. Wood density measurements made on the consecutive five-year sections along the southern radius were used to indicate wood density variation with age. Widths of the five-year sections, as well as the physical distance from the pith to the midpoint of each section, were recorded.

Benzene-alcohol extractives in aspen wood are known to comprise approximately 5% of the dry weight of wood (Pearl and Harrocks 1961). Since extractives are a group of organic compounds extraneous to wood, all wood samples from the southern radius were subjected to two-stage extraction in benzene-alcohol solutions (50:50 benzene-ethanol followed by 95% ethanol) in soxhlet apparatus for 8-h periods. After organic chemical extraction, samples were boiled in a large volume of distilled water for 8 h to remove hot-water-soluble extractives.

Data were analyzed by a split-plot analysis of variance and covariance (Steele and Torrie 1980). Since clones and trees within clones (nested) were considered to be random effects, least-squares means were not calculated for each of these effects. Means presented are simple means calculated for the four trees in each clone or for all twelve trees in the three clones. Significance was tested at the 0.05 level of probability in all cases.

RESULTS AND DISCUSSION

The analysis of variance, carried out on whole wedges from the four cardinal directions at each height, indicated that significant differences existed among the three sampled clones (Table 1). This is somewhat surprising in view of the small number of clones used in this study. Brown (1961) also found significant differences in wood density among four clones of trembling aspen in New York. While

TABLE 1. *Analysis of variance of unextracted within-stem wood density in aspen determined on four 10-degree wedges at five sample heights from four trees from each of three clones in north-central Alberta.*

SOURCE	DF	MEAN SQUARES	F
Clones	2	0.003084	4.85*
Trees/Clones	9	0.000636	
Height	4	0.004173	12.35**
Direction	3	0.000167	0.49
Ht. x Direc.	12	0.000338	1.60
Clone x Ht.	8	0.001123	5.32**
Trees/C x Ht.	36	0.000384	1.82
Clone x Direc.	6	0.000221	1.04
Trees/C x Direc.	27	0.000140	0.66
Error	132	0.000211	

** significant at the 1% level.
* significant at the 5% level.

this study was not designed to test differences among clones, it is apparent from even this small sample that interclonal variation is an important component of phenotypic variation of wood density. In another paper (Yanchuk et al. 1983), we present results of a study of interclonal variation.

There also were significant differences among the five sampling heights within trees (Table 1). Wood density is high at the base of the tree, decreases at mid-height, and increases near the tree top (Fig. 1). Similar patterns of wood density

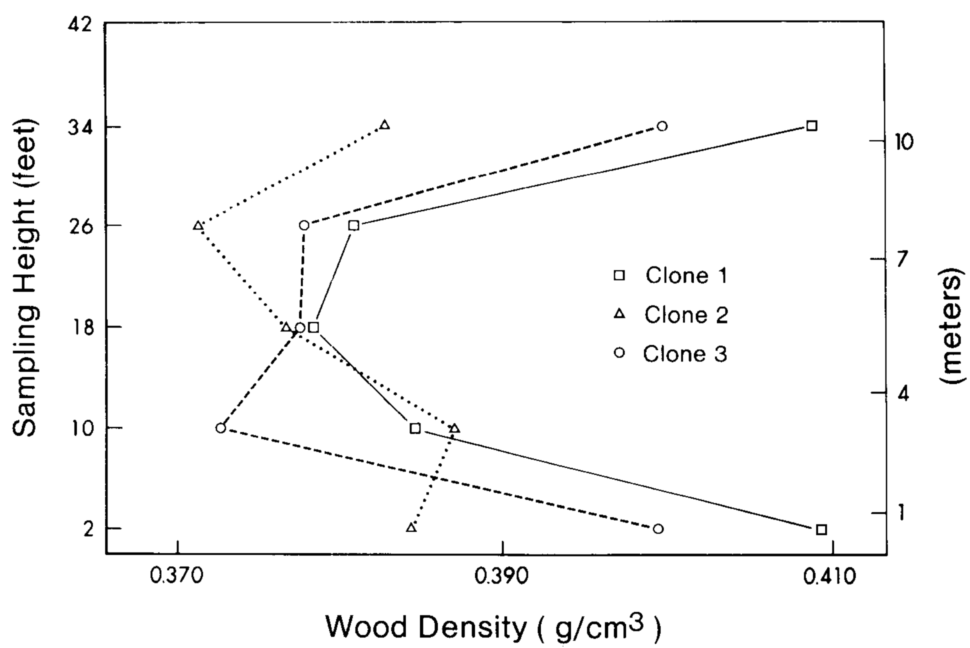

FIG. 1. Unextracted wood density variation within stems of aspen at five sampling heights for three clones in north-central Alberta. Each plotted value is the mean for the 16 10-degree wedges.

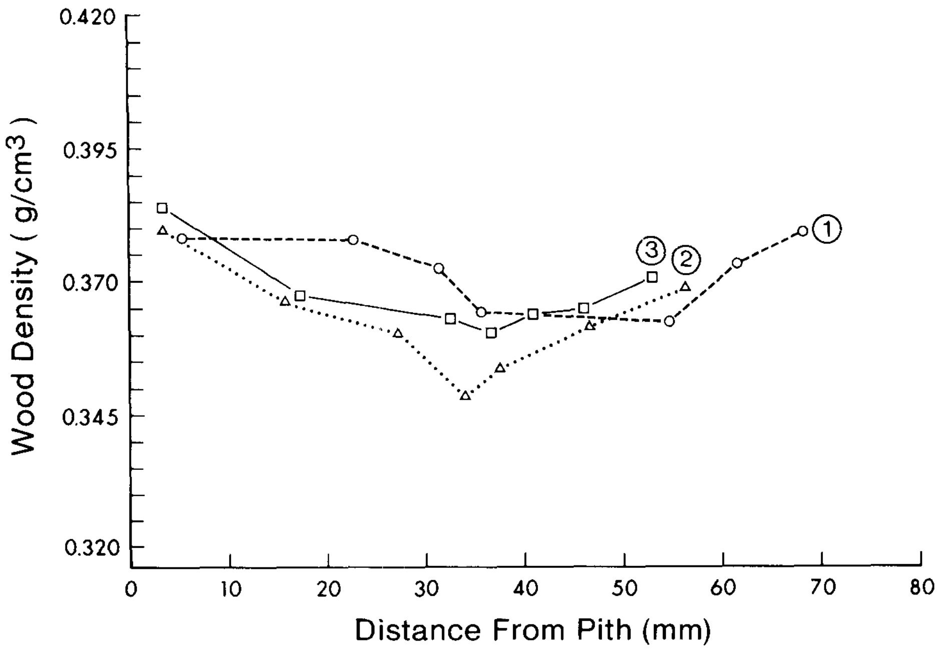

FIG. 2. Extracted wood density variation in aspen for three clones in north-central Alberta. Each plotted value is the average of all 5-year increments for each clone at the average distance from the pith the sections occurred.

variation in the axial direction have also been shown in *Eucalyptus grandis* Hill ex Maiden (Taylor 1973) and *Celtis laevigata* Willd. (Taylor and Wooten 1973).

No significant differences among radial directions within sampling heights were found (Table 1). Walters and Bruckmann (1965) also found that wood density did not differ significantly between north and south cardinal directions at the same height in *Populus deltoides* (Bartr.). This suggests that sampling from one radius adequately represents wood density at any height.

Interaction terms for the various sources of variation were not significant, with the exception of "clone × height" (Table 1). It is doubtful that this relationship (shown in Fig. 1) is very meaningful, because the samples at fixed height intervals did not correspond to similar crown positions in all trees. The interaction may be the presence of crown-formed (juvenile) wood in some samples and its absence in others.

In all three clones, wood density is high near the pith, drops a short distance from the pith, and increases near rings 15–20 (approximately 30 mm from the pith) (Fig. 2). Variation across the southern radius at five sampling heights for one selected clone (Clone 2) is illustrated in Fig. 3. The pattern of high wood density near the pith with decreasing density throughout rings 15–20 occurs at every sampling height (Fig. 3). Clones 1 and 3 also exhibited similar patterns of variation (Yanchuk 1982).

The presence of high wood density near the pith also has been found in other species. Panshin and DeZeeuw (1980) described this pattern of variation as typical

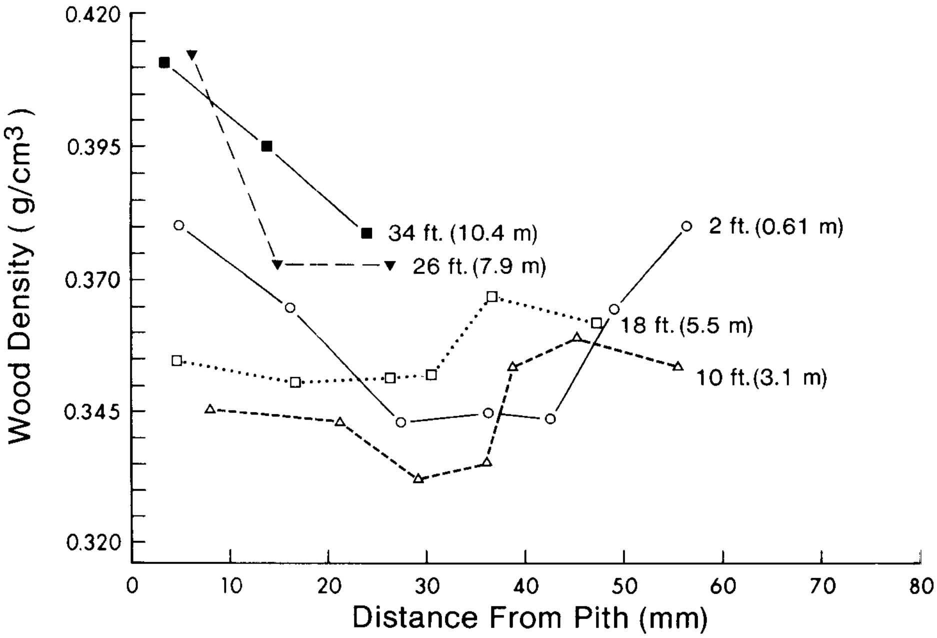

FIG. 3. Extracted wood density variation from four aspen trees from one clone (Clone 2) at five different sampling heights with distance from the pith.

of *Populus*. Isebrands (1972) found that wood produced by the juvenile crown of eastern cottonwood usually had a lower percentage of vessels than did the wood formed by a more mature crown. Further, he reported a noticeable decrease in the percentage of fibers as distance from the pith increased and as tree height increased. If similar differences exist in aspen, the percentage and size of vessels

TABLE 2. *Analysis of covariance of extracted wood density within stems of aspen determined on 5-year sections from southern radius at five sample heights from four trees from each of three clones in north-central Alberta.*

SOURCE	DF	MEAN SQUARES	F
Clones	2	0.003017	6.11*
Trees/Clones	9	0.000494	1.00
Height	4	0.010127	20.51**
Section	6	0.001615	3.27**
H x S	15	0.000694	1.41
Regression			
X1(section width)	1	0.005789	11.73**
Error	274	0.000494	

regression coeffecient=b(X1)=0.0014698

** significant at the 1% level.
* significant at the 5% level.

and fibers may be the major underlying causes of wood density variation with height and diameter.

The analysis of variance model was deliberately modified a number of times in an attempt to account for the large variation of wood density across the radius. The covariate "distance from pith," which accounts for the number of cell divisions from the pith irrespective of incremental age, was not significant. Brown and Valentine (1963) also found that using "distance from the pith" did not increase the predictability of their linear model for wood density distribution across a radius in aspen. The analysis using the 5-year sections as a source of variation and section widths as a covariate was therefore the most appropriate model (Table 2). "Clones," "height," and "sections" were significant. This analysis, while explaining more of the variation within trees, clearly increased the F ratio among the three clones (Table 2). This is perhaps the reason why Van Buijtenen et al. (1959) suggested that a majority of the variation present in wood density is among trees within clones. Interclonal differences cannot be adequately assessed unless the variation within stems is accounted for, preferably by the inclusion of specific increment periods (i.e., 5-year "sections" in this study) as a source of variation (Table 2).

The width of the 5-year sections (the covariate "section width" representing growth rate over a 5-year period) was significant (Table 2), suggesting that as ring width increases, wood density also increases (b = 0.0014698). This is in contrast to other reports, which generally indicate a slight negative correlation between rate of growth and wood density in *Populus* (Kennedy 1968; Kennedy and Smith 1959). The positive regression coefficient may be due to the interaction of two factors. The wider rings and corresponding high wood densities near the pith are represented more than wood from other locations within trees, simply because there are unequal numbers of growth rings (i.e., 5-year "sections") at each sample height. The comparison of anatomically different wood (i.e., wood formed at different age and heights) with an independent variable such as growth rate may incorrectly imply a relationship between the two traits. Although the regression coefficient may not accurately explain the growth rate relationship, it does indicate the overall average effect of differences in growth rate among the 5-year samples within trees. Removing the covariate "section widths" from the analysis did not significantly change F ratios for "clones" or "sections."

The overall pattern of variation in wood density within stems is portrayed schematically in Fig. 4. The values in each cell represent the average wood density (adjusted for section width) for each 5-year section at a particular sample height and increment period for all twelve stems examined. Large differences in wood density are present among the sampling positions, with a minimum average value of 0.348 g/cc at 3.1 m (rings 11–15) and a maximum average wood density of 0.402 g/cc at the top of the tree (rings 1–5) (Fig. 4). It is obvious that the position in the tree and age of the tree need to be considered when estimating wood density in aspen trees.

Although relatively high wood densities may be present in younger trees, the extremely short fibers present in juvenile stems (Einspahr et al. 1972) substantially reduce the quality of wood in these portions of stem. Clearly, detailed investigations of the proportions and sizes of cells near the pith (and elsewhere) and

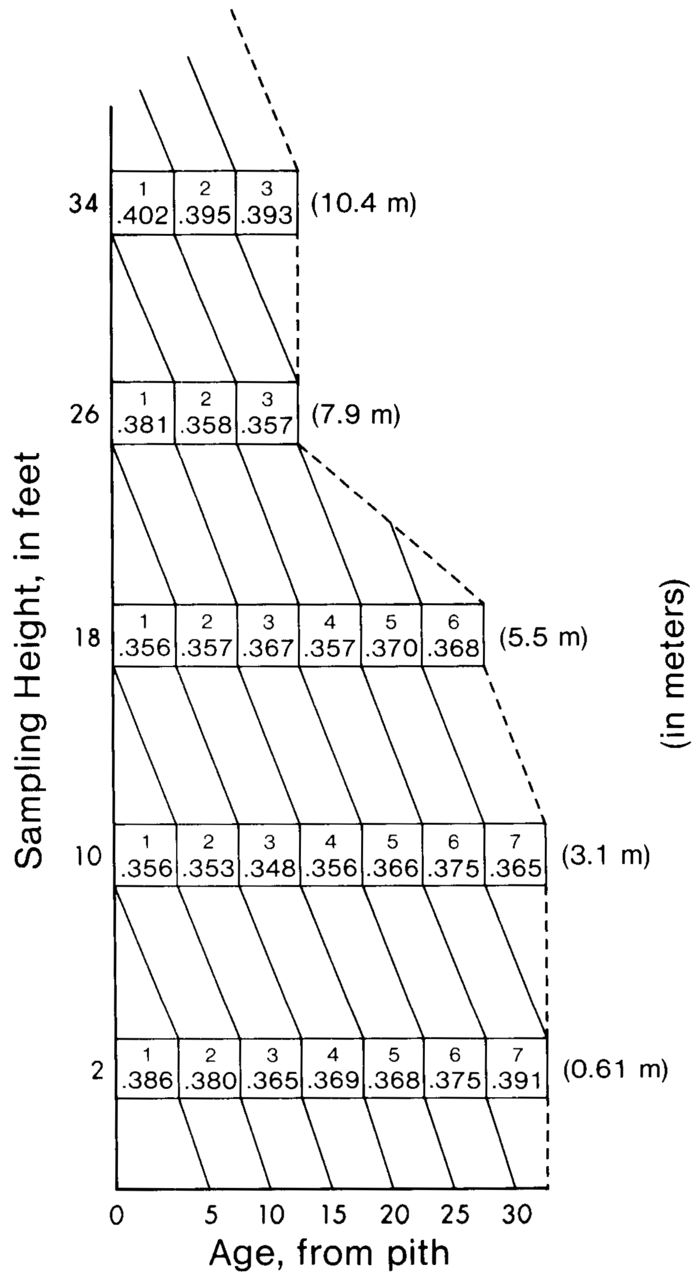

FIG. 4. Schematic drawing of extracted wood density variation within stems of aspen from north-central Alberta. Least-squares means are derived from twelve trees adjusted for average widths of 5-year sections.

their utility in papermaking must be pursued. Finally, although a genetic basis for differences in wood density among clones can only be inferred from this study, we believe that such a case can be made.

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