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SPECIFIC GRAVITY AND FIBER LENGTH VARIATION IN A EUROPEAN BLACK ALDER PROVENANCE STUDY¹

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ABSTRACT

Specific gravity and fiber length variation among 13 provenances of *Alnus glutinosa* were studied. Based on mean provenance values, specific gravity varied from 0.37 to 0.42, and fiber length varied from 0.68 mm to 1.01 mm. Single-tree maximum values were slightly higher. Analysis of variance indicated no significant differences among provenances for either trait. Patterns of variation from pith to bark and from the base to top of the tree are presented. The potential for genetic improvement of these traits is discussed.

Keywords: Wood quality, *Alnus*, specific gravity, fiber length, genetic improvement.

INTRODUCTION

European black alder (*Alnus glutinosa* (L.) Gaertn.) has potential to be utilized for lumber, composites, pulp, and biomass for energy. To identify sources of this species with desirable characteristics for these uses, information on the variation in wood quality traits is needed. Two important traits are specific gravity and fiber length.

Previous studies state that average stem specific gravity in European black alder ranges from 0.43 (Vurdu and Benseid 1979) to 0.49 (Morin 1974) in older trees and from 0.30 to 0.40 in 2-year-old material (Kellison and White 1979; Geyer

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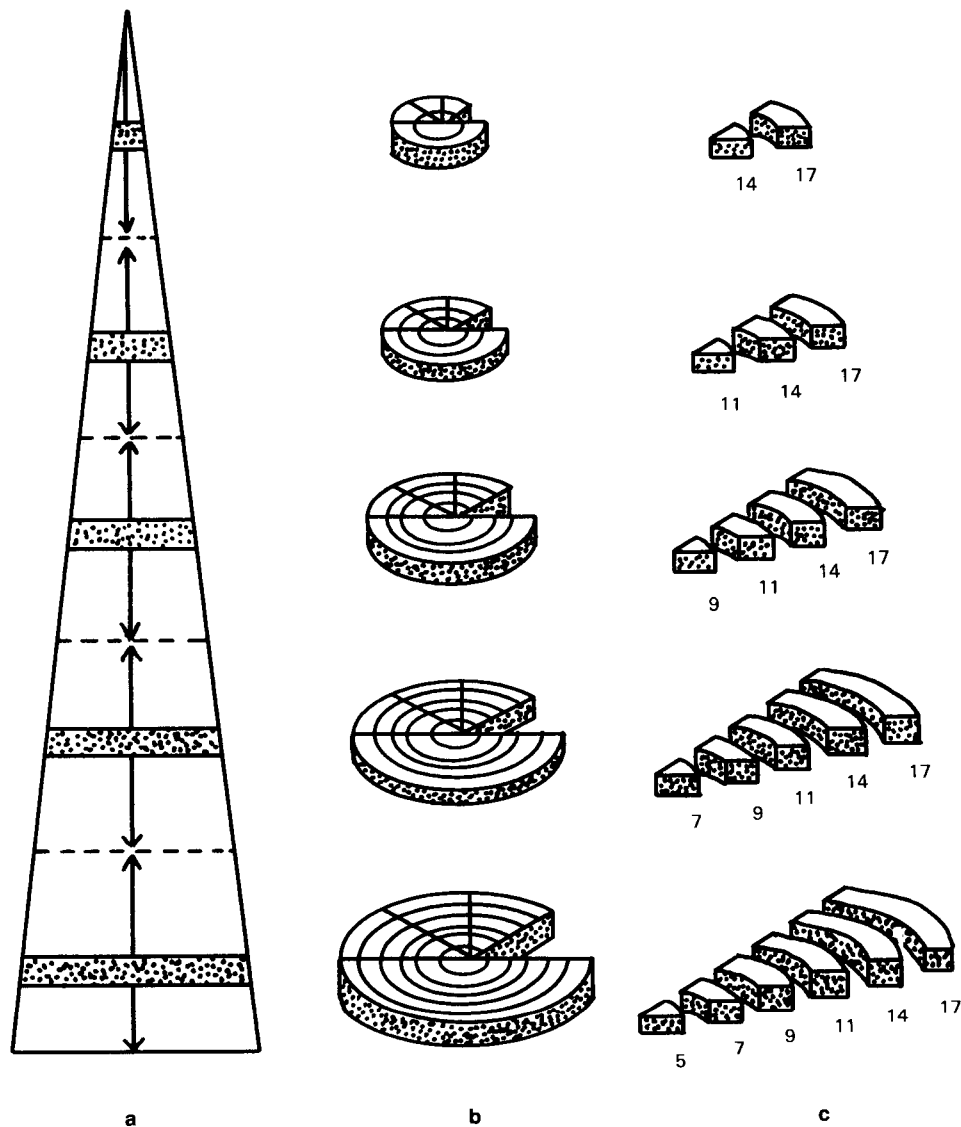


FIG. 1. Sampling scheme for specific gravity and fiber length determinations: a) five disks (stippled areas) were removed from each tree to represent the wood from areas of the stem between dashed lines, b) four wedges were cut from each disk, and c) the wedges were divided into growth segment samples along growth rings representing plantation ages 5, 7, 9, 11, 14, and 17.

1981). Average fiber length has been reported to be 0.89 mm (Brunn and Sluun-gaard 1957), 0.80 mm to 0.95 mm (Haarlea and Karkkainen 1982), or varying from 0.89 mm to 0.80 mm from bottom to top of stems (Vurdu and Bensend 1979) in older trees. The range in 2-year-old trees was 0.95 mm to 1.33 mm (Kellison and White 1979). These studies, however, were based on small sample sizes of unknown or very limited genetic background.

TABLE 1. Mean provenance specific gravity and minimum and maximum individual tree specific gravity for 6 ages of *Alnus glutinosa* based on whole-tree estimates.

	Age					
	5	7	9	11	14	17
Provenance ^a						
46	0.42 (0.009) ^b	0.42 (0.006)	0.42 (0.012)	0.41 (0.005)	0.41 (0.005)	0.42 (0.002)
28	0.39 (0.010)	0.39 (0.007)	0.40 (0.003)	0.40 (0.003)	0.40 (0.008)	0.41 (0.011)
48	0.38 (0.016)	0.40 (0.003)	0.40 (0.006)	0.39 (0.008)	0.40 (0.011)	0.41 (0.011)
58	0.41 (0.018)	0.41 (0.018)	0.40 (0.019)	0.40 (0.018)	0.40 (0.020)	0.41 (0.017)
18	0.42 (0.036)	0.40 (0.020)	0.39 (0.016)	0.40 (0.014)	0.40 (0.011)	0.41 (0.010)
49	0.38 (0.024)	0.40 (0.013)	0.39 (0.012)	0.39 (0.011)	0.39 (0.009)	0.40 (0.007)
56	0.38 (0.010)	0.37 (0.010)	0.37 (0.009)	0.38 (0.009)	0.39 (0.005)	0.40 (0.005)
44	0.38 (0.018)	0.38 (0.012)	0.38 (0.012)	0.39 (0.014)	0.39 (0.016)	0.39 (0.018)
24	0.39 (0.005)	0.40 (0.008)	0.39 (0.004)	0.39 (0.002)	0.39 (0.002)	0.39 (0.005)
43	0.41 (0.045)	0.39 (0.011)	0.39 (0.002)	0.39 (0.004)	0.39 (0.005)	0.39 (0.001)
53	0.40 (0.014)	0.40 (0.017)	0.40 (0.017)	0.39 (0.017)	0.39 (0.017)	0.39 (0.018)
45	0.39 (0.015)	0.39 (0.010)	0.39 (0.011)	0.38 (0.008)	0.39 (0.003)	0.39 (0.007)
54	0.37 (0.009)	0.38 (0.016)	0.37 (0.017)	0.37 (0.018)	0.38 (0.022)	0.39 (0.023)
Overall mean	0.39	0.40	0.39	0.39	0.39	0.40
Individual tree:						
Minimum	0.33	0.34	0.34	0.34	0.33	0.34
Maximum	0.50	0.44	0.45	0.44	0.44	0.44

^a Provenance numbers correspond to those described in Funk (1973, 1979).^b Specific gravity (standard error of the mean).

The purpose of this study was to clarify and add to the data base available on specific gravity and fiber length variation in European black alder to aid improvement efforts for this species. Data are presented on variation of these traits among provenances, within trees, and over time.

MATERIALS AND METHODS

Thirty-nine trees from a 17-year-old provenance test located on a coal spoil in Ohio (Funk 1973, 1979) were analyzed in this study. These trees represented 13 of the original 15 provenances in Funk's study. The provenance test was arranged in a randomized complete-block design with three blocks. One representative tree was harvested from each provenance in each block.

Data obtained from stem analysis of these trees (Robison 1984) allowed five disks containing 14, 12, 10, 8, and 6 annual rings, respectively, to be removed from each stem (Fig. 1a). Four, 45° wedges were cut from each disk, avoiding branch traces when possible (Fig. 1b). Two were used for specific gravity determinations and two for fiber length measurements. Each wedge was subdivided into growth segment samples along rings corresponding to plantation ages 5, 7, 9, 11, 14, and 17 years (Fig. 1c). Each sample was labeled using a coordinate system developed by Balodis (1966).

The maximum moisture content method was used to determine specific gravity (Smith 1954). The specific gravity was calculated by the formula:

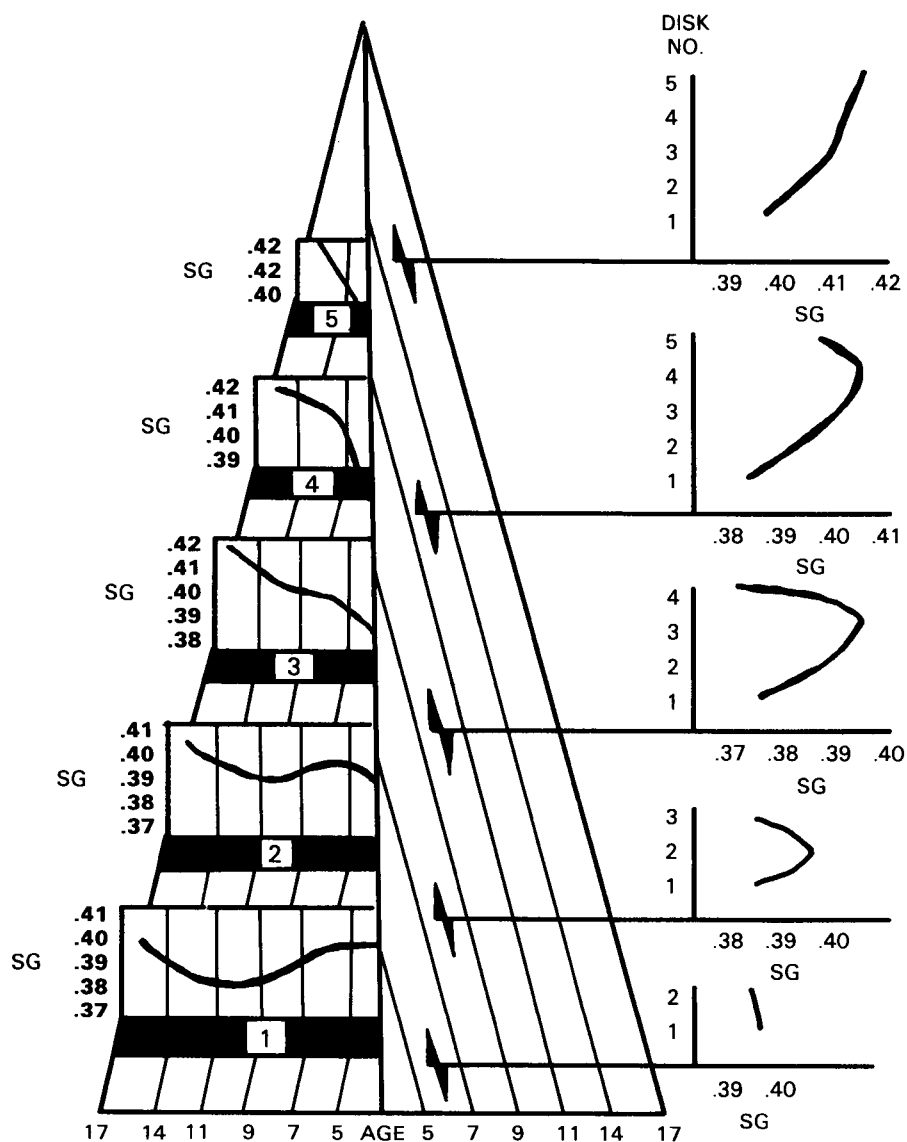


FIG. 2. Radial variation in average specific gravity at five heights (left), and axial variation in five growth segments (right) for *Alnus glutinosa* based on a 39 tree sample.

$$G_f = \frac{1}{((M_m - M_o)/M_o + (1/G_{so}))} \quad (1)$$

where

- G_f = specific gravity based on green volume
- M_m = weight of saturated wood sample
- M_o = weight of oven-dried sample
- G_{so} = average density of wood substance = 1.53.

TABLE 2. Mean provenance fiber length and maximum and minimum individual tree fiber length for 6 ages of *Alnus glutinosa* based on whole-tree estimates.

	Age					
	5	7	9	11	14	17
Provenance ^a						
56	0.74 (0.063) ^b	0.88 (0.055)	0.92 (0.042)	0.95 (0.034)	0.98 (0.028)	1.01 (0.024)
18	0.73 (0.032)	0.82 (0.012)	0.90 (0.036)	0.92 (0.038)	0.97 (0.042)	1.00 (0.040)
28	0.71 (0.026)	0.79 (0.007)	0.85 (0.010)	0.89 (0.008)	0.93 (0.012)	0.96 (0.012)
58	0.72 (0.035)	0.80 (0.012)	0.84 (0.010)	0.87 (0.000) ^c	0.92 (0.005)	0.95 (0.005)
49	0.70 (0.060)	0.79 (0.064)	0.85 (0.070)	0.87 (0.071)	0.90 (0.077)	0.93 (0.082)
45	0.70 (0.039)	0.78 (0.033)	0.83 (0.019)	0.86 (0.017)	0.91 (0.024)	0.93 (0.025)
43	0.68 (0.054)	0.78 (0.032)	0.85 (0.031)	0.86 (0.034)	0.90 (0.036)	0.93 (0.040)
54	0.75 (0.035)	0.83 (0.018)	0.87 (0.014)	0.88 (0.016)	0.90 (0.017)	0.92 (0.019)
48	0.68 (0.037)	0.79 (0.035)	0.83 (0.042)	0.85 (0.041)	0.88 (0.036)	0.91 (0.038)
24	0.67 (0.039)	0.78 (0.012)	0.84 (0.012)	0.86 (0.023)	0.90 (0.038)	0.91 (0.041)
44	0.72 (0.039)	0.79 (0.018)	0.85 (0.017)	0.87 (0.014)	0.89 (0.019)	0.91 (0.017)
46	0.69 (0.010)	0.77 (0.008)	0.82 (0.015)	0.84 (0.012)	0.87 (0.019)	0.89 (0.028)
53	0.71 (0.010)	0.78 (0.030)	0.83 (0.014)	0.84 (0.010)	0.86 (0.016)	0.88 (0.018)
Overall mean	0.71	0.80	0.85	0.87	0.91	0.93
Individual tree:						
Minimum	0.58	0.71	0.75	0.79	0.79	0.81
Maximum	0.86	0.99	1.00	1.02	1.05	1.09

^a Provenance numbers correspond to those described in Funk (1973, 1979).^b Fiber length in millimeters (standard error of the mean).^c Standard error of the mean is less than 0.0005.

Samples for fiber length measurements were macerated in a 1:1 solution of glacial acetic acid and 30% hydrogen peroxide at 60 C, then rinsed 3 × 30 minutes in distilled water (Franklin 1946). For each sample, a drop of macerated tissue was placed on a microscope slide, stained with Safrinin, and covered. The slide was placed in a slide holder and projected onto a screen. Fifteen whole fibers per sample were measured to the nearest 1 mm at 90× magnification.

A weighting scheme was used to estimate whole-tree specific gravity and fiber length of each tree for ages 5, 7, 9, 11, 14, and 17. The weighting factor for fiber length equaled the volume that each growth segment sample represented in the whole tree divided by the whole-tree volume. A whole-tree fiber length value was calculated by combining weighted sample values for a particular year and all younger years.

For specific gravity, the whole-tree values were obtained by combining the actual dry and saturated weights separately for a particular year and all younger years in each tree. Then these weights were inserted into Smith's formula to calculate the whole-tree value for that year.

The sampling procedure was used so that comparisons between trees were based on wood of similar physiological age (Richardson 1961). The variability of wood within a tree is caused by environmentally modified physiological gradients originating in the crown and proceeding down the stem (Larson 1969). Statistical sampling should take into consideration these biological variation patterns (Richardson 1961; Larson 1969). Because of the relationship between the growing shoot tips that regulate cell-wall formation and a particular position in a tree, it was

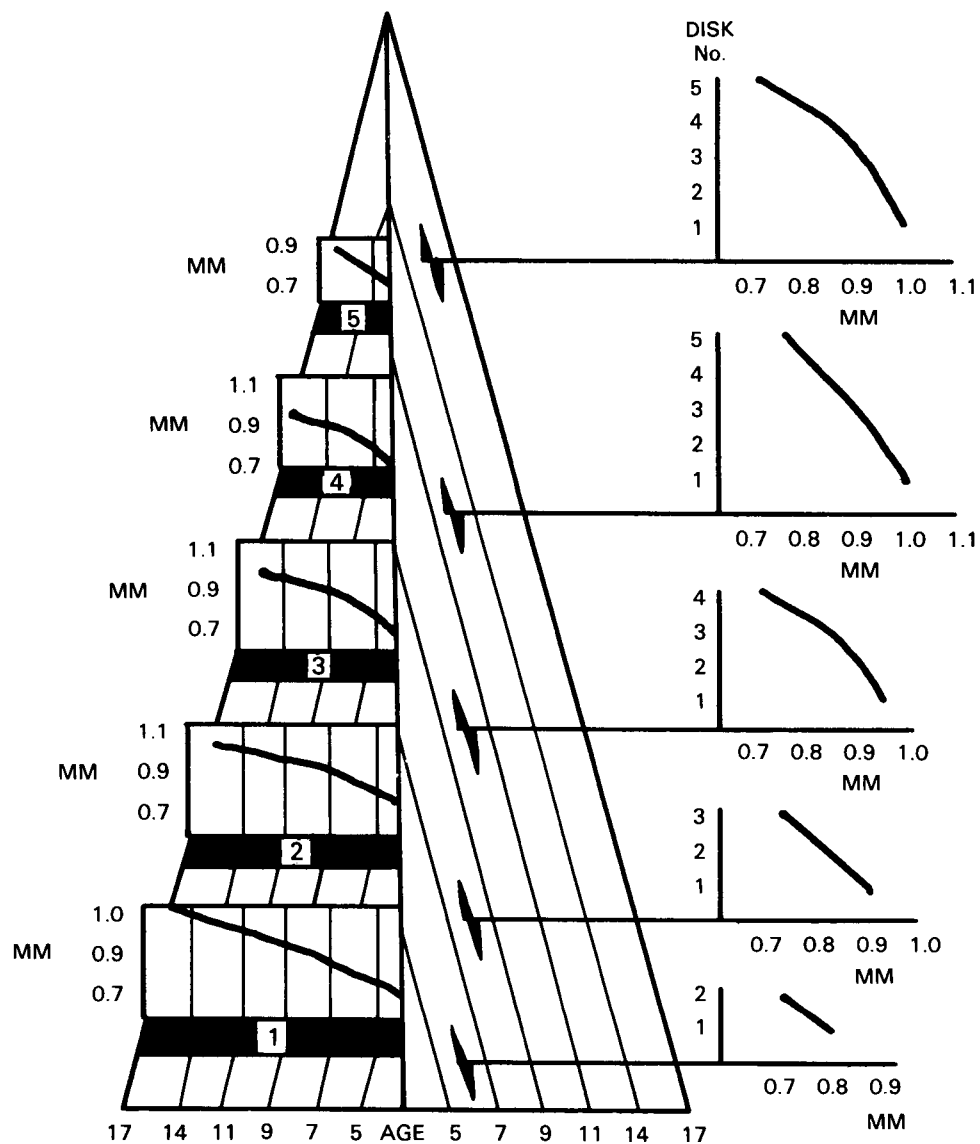


FIG. 3. Radial variation in average fiber length at five heights (left), and axial variation in five growth segments (right) for *Alnus glutinosa* based on a 39 tree sample.

assumed that disks with the same number of rings were more likely to have been formed at similar physiological stages than disks removed at fixed intervals or fixed percentage intervals along the stems. This sampling procedure also allowed radial and axial variation patterns to be studied.

RESULTS AND DISCUSSION

Specific gravity based on provenance means ranged from 0.37 to 0.42, and individual-tree values ranged from 0.33 to 0.50 (Table 1). There were no significant

differences among provenances at any age, and no relation between specific gravity and age of sample material. Averaged over all trees, specific gravity increased slightly across disks from the pith outwards except in the lower two disks, where there was an initial decrease followed by an increase (Fig. 2). With height, specific gravity increased slightly in the outermost growth segment (youngest wood), slightly increased then decreased in the middle three growth segments, and remained constant in the innermost growth segment (oldest wood) (Fig. 2).

Mean provenance fiber length ranged from 0.68 mm to 1.01 mm with individual-tree values ranging from 0.58 mm to 1.09 mm (Table 2). As was found for specific gravity, whole-tree fiber length did not vary significantly among provenances at any age. Fiber length variation across disks and within growth segments followed a more predictable pattern than did specific gravity. Fiber length, averaged over all trees, increased from pith to bark in all disks and decreased from the base of the tree upwards in all growth segments (Fig. 3). The increase in average fiber length across disks is common to many tree species (Dinwoodie 1961) and has been noted in European black alder previously (Haarlea and Karkainen 1982).

The overall mean values for fiber length and specific gravity in this study are somewhat lower than those reported previously by Morin (1974) and Vurdu and Bensend (1979), although single-tree values were in some instances greater. The differences probably resulted from random sampling variation because of the small sample sizes. The trees used in the present study were grown on a coal spoil, and the resulting site factors and slow growth may have resulted in lower values. It is difficult to predict the effect that a coal-spoil environment would have on the quality of wood produced from the trees grown there because of the lack of data on this subject. Decreases in specific gravity and fiber length with slow growth have been noted in *Populus* and *Eucalyptus* (Panshin and deZeeuw 1980).

Heritability, which is a measure of resemblance between offspring and parents, has been on the order of 0.40 or more for both traits in other species studied (Wilcox 1977; Namkoong et al. 1969; Smith 1967); therefore, genetic improvement for these traits seems feasible. Because there was no correlation between either trait and latitude of provenance origin, and no significant variation among the provenances sampled in this study, mass selection should be used to improve these traits. Sampling more seed sources from throughout the native range of European black alder may reveal significant variation among provenances, but results from most studies agree that tree-to-tree variation in wood properties overshadows provenance variation (Einspahr et al. 1962). Provenances should first be identified with superior growth properties and adaptability; then, mass selection for specific gravity and fiber length should be used to select superior individual trees within this group.

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