HEARTWOOD FORMATION IN FOUR BLACK WALNUT PLANTATIONS

Keith Woeste and Brian Beheler[1]

The amount of heartwood in black walnut (*Juglans nigra* L.) logs can vary widely, even among trees of the same age growing at the same location. There is little published data on the genetics, physiology, and development of heartwood in hardwoods, even though the volume of heartwood in a log can significantly influence its value.

We analyzed trees from four black walnut populations for growth, the volume of sapwood and heartwood, area of heartwood and percent heartwood area (table 1). Phenotypic correlations among the traits were determined to evaluate the feasibility of using such correlations for the improvement of black walnut breeding stock for percent heartwood area.

Tree diameter was measured at 1.4 m above ground (DBH) and/or at the stump after felling. The area and percent area of heartwood were calculated using increment cores (at DBH) or by measuring the heartwood and sapwood of felled trees at the stump and/or at DBH. The trees measured at Martell and Salamonie were the fastest growing trees in the stand (the trees remaining after silvicultural thinning). The trees measured at SEPAC and ShoNeff were the individuals being removed as part of a planned thinning.

The site conditions at all four plantations were excellent, as was reflected in the growth rate of the trees. There was no clear relationship between growth rate and percent heartwood. The depth of the bark averaged 0.51 ± 0.1 inches. The heartwood core in walnut was typically conical and significantly larger at the stump than at DBH. The heartwood cone was not centered in the tree but was shifted slightly to the north and east, and trees at the southern and western edges of plantations had slightly more heartwood than trees in the interior.

Growth (diameter and height) was consistently highly correlated with heartwood area (table 2). There was also a significant and strong positive correlation between heartwood area and percent area of heartwood (PAOH) both at the stump and at DBH. Estimates of the correlation between percent heartwood area and diameter were extremely variable, ranging from –0.45 to 0.74, and were frequently non-significant. Estimates of PAOH were probably most accurate when based on trees cut at DBH, because trees are rounder and the heartwood is more circular at this point than at the stump.

As a tree increases in diameter, the percent area of a cross section that was heartwood (PAOH) increased more quickly than the percent that

Table 1.—*Characteristics of the populations used in this study*

Population	Population type	Location	n	Year established	Growth (in/yr)	Mean % heartwood (± SD)
Martell	Grafted	Tippecanoe, IN	77	1975	0.3	46 ± 9
SEPAC	Seedlings	Butlerville, IN	76	1981	0.4	31 ± 11
ShoNeff	Seedlings	Stockton, MO	296	1974	0.4	42 ± 12
Salamonie	Seedlings	Lagro, IN	80	1963	0.26	47 ± 7

[1] Molecular Geneticist (KW), Hardwood Tree Improvement and Regeneration Center, USDA Forest Service, and Forest Manager (BB), Martell Forest, Department of Forestry and Natural Resources, 1159 Forestry Building, Purdue University, West Lafayette, IN 47907. KW is corresponding author: to contact, call (765) 496-6808 or e-mail at kwoeste@fs.fed.us.

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was sapwood. The timing and rate of the expansion of heartwood and sapwood may depend on tree age, site, and genotype.

It was often difficult to identify a single point at which the sapwood ended and heartwood began. This was true both when samples were taken by increment core and when heartwood was measured directly from a log or stump. This difficulty in measurement complicated the estimation of PAOH. As a consequence, our estimates of PAOH varied considerably within a single tree, depending on how and where measurements were made.

The coefficient of variability (CV) for sapwood depth for even-aged trees was twice the CV for diameter. It is not clear how much of this variance was due to measurement error, how much was environmental, and how much was related to differences among genotypes. Precise measures of sapwood depth are important because small differences in sapwood depth created large differences in estimates of heartwood area and PAOH. Despite these difficulties, there were significant differences among families for heartwood area and PAOH in all of the populations we studied. However, without improved methods for measuring the amount of heartwood in a log and/or standing tree, genetic improvement for PAOH will be difficult, and these will be achieved only in the short term as a correlated response to selection for diameter growth.

Table 2.—*Spearman correlation coefficients for the relationships among growth and heartwood characters in four populations of walnut*

	Heartwood area (cm^2) at DBH	**Percent area heartwood at DBH**	**Percent area heartwood at stump**	**Percent area heartwood (incr. core)**
DBH	0.67-A[1,2] 0.76-C 0.94-D	NS-A NS-C	NS-A -0.23-C	NS-C 0.21-D
Total area	0.75-C 0.95-D	NS-C	-0.23-C	NS-C 0.21-D
Height	0.61-A 0.31-C	NS-C	0.31-A	0.21-A
Heartwood area	1.0	0.76-A 0.49-C	NS-C	0.37-C 0.47-D
Stump diameter	0.71-A 0.79-B 0.65-C	NS-C	0.23-A 0.74-B -0.45-C	NS-C
Heartwood area (at stump)	0.79-B 0.62-C	0.37-C	0.77-B 0.61-C	0.41-C

[1] All correlations are significant at $\alpha = 0.05$, NS = not significant.
[2] Letters after correlation statistic refer to populations from which estimates were obtained; A = SEPAC, B = ShoNeff, C = Martell, D = Salamonie, see table 1.