# Black Walnut for Gunstocks

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For nearly a century, black walnut has been used almost exclusively for gunstocks by manufacturers of both military and civilian firearms. On the whole, the choice has proved a sound one: the wood has adequate strength and durability, holds its shape-well when subjected to conditions which might cause other species to warp, and can be beautifully finished.

During the years this species has been preeminent in the gunstock field, however, the conditions which prevailed and, in part at least, influenced its early selection have been substantially changed. Of particular importance among these changes has been the gradual disappearance of the old, virgin growth, forest-grown stock and the emergence of so-called "open-grown'' material—that is, trees growing singly or in small scattered groups in pastures and relatively open farm woodlots.

These changed growth conditions, coupled with the fact that comparatively little study of the physical characteristics of this wood has ever been made, prompted the Forest Products Laboratory in 1942 to undertake a closer scrutiny of black walnut as it exists in the United States today.

One purpose of this study was to ascertain the effects, if any, which these changing conditions of growth have had upon the physical properties of the wood—its slope of grain, dimensional stability, weight, and hardness. A secondary objective was to obtain more complete and accurate data upon these properties so that, if and when necessary, such knowledge could be used to judge the comparative worth of other species as substitute gunstock materials.

Accordingly, material was obtained for these studies from both open- and forest-grown trees (Fig. 1) mainly on National Forest lands in Wisconsin, Ohio, southern Indiana, northern Georgia, and the Ozark region of Arkansas and Missouri. These trees were grown in different soil regions such as sandstone and shale, limestone, and alluvial areas. The main features of the locations and forests from which the samples were obtained are given in Table 1. In Table 2 are presented the ages and diameters of each group of trees from which test specimens were taken.

These black walnut samples consisted of full cross-sections 1 foot in length along the grain from just above the stump and, usually, from two or more other places in the merchantable length of the log. The heights in the tree from which the samples were cut necessarily varied with the form of the tree; but in all cases efforts were made to secure samples between the 8-foot and 16-foot levels in order to facilitate comparison of test results with those of earlier Forest Products Laboratory studies of black walnut. The samples were protected from excessive drying in shipment by moisture-retardant coatings applied to the ends.

At the Laboratory, these samples were tested for specific gravity, hardness, volumetric shrinkage, linear shrinkage in the radial, tangential, and longitudinal directions, and straightness of grain. Specific gravity determinations offer a good means of estimating such properties of a wood as its hardness, bending strength, and resistance to shock; in this study, however, hardness, which varies approximately with the $2^{1}/_{2}$ power of specific gravity, was determined by actual test. Shrinkage of a species, especially as it varies between radial and tangential directions and between sapwood and heartwood, indicates to what extent the wood will warp, twist, or cup when exposed to changing moisture conditions. Slope of grain in a piece of wood is indicative of its strength in bending and shock resistance; straight-grained wood possessing greatest serviceability, with such defects as spiral and interlocked grain contributing to structural weakness.

**Specific Gravity Tests**

All specific gravity values given in this report are based upon the weight of the specimen when oven dry and its volume when green. The volume of all specific gravity specimens was determined in an oven-dry condition to obtain volumetric shrinkage data.

Specific gravity determinations in these studies definitely established a tendency for wood of open-grown trees to be somewhat heavier than that of forest-grown trees. Tests of material taken from all heights in the tree showed an average specific gravity for open-grown trees of 0.55, while that of forest-grown trees was 0.51. Specific gravity values from all specimens tested ranged from a low of 0.40 to a high of 0.67, with an average of 0.52 (Fig. 2, A). When material above and below the 8- to 19-foot level was excluded, the maximum specific gravity was reduced to 0.61 (Fig. 2, B). Table 2 gives specific gravity values for samples from different locations and different stands, at different heights in the tree, and for heartwood, sapwood, and combinations of both, together with average data on rate of growth (rings per inch) for the various groups of specimens,

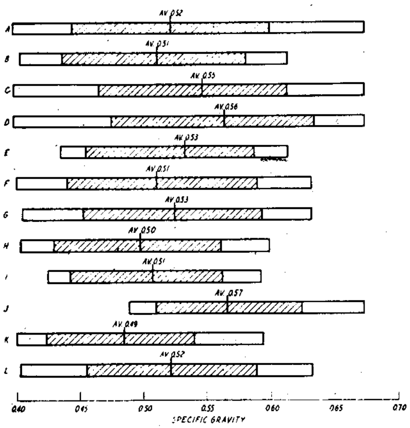


*Figure 2—Variation in specific gravity of black walnut:*

(A) Range for specimens from all trees at all heights (1,179 specimens)
(B) Range for material 8 to 19-foot level in all trees (423 specimens)
(C) Range for material from open-grown trees at all heights (378 specimens)
(D) Range for material at base of open-grown trees (155 specimens)
(E) Range for material 8 to 19-foot level, open-grown trees (167 specimens)
(F) Range for material. all heights, in forest-grown trees (801 specimens)
(G) Range for material at base of forest-grown trees (298 specimens)
(H) Range for material at 8 to 19-foot level in forest-grown trees (256 specimens)
(I) Range for sapwood of open-grown trees (44 specimens)
(J) Range for heartwood of open-grown trees (240 specimens)
(K) Range for sapwood of forest-grown trees (111 specimens)
(L) Range for heartwood of forest-grown trees (616 specimens)

*The average value is shown for each group. The shaded portion of each bar represents the middle 90 per cent of the specimens. Specific gravity values in this figure are bared upon the weight of the specimens when oven dry and their volume when green.*

Black walnut sapwood had a lower average specific gravity than did heartwood in both open-grown and forest-grown specimens. Frequently, large differences were found between adjacent pieces of heartwood and sapwood cut from the same log. The average sapwood value for open-grown trees was 0.51 and that of forest-grown trees 0.49 (Fig. 2, I, K, and Table 2). Heartwood of open-grown trees averages 0.57 in contrast to an average of 0.52 for that of forest-grown trees (Fig. 2, J. L).

The lower specific gravity of sapwood may be accounted for in two ways: retarded growth during recent years in both open- and forest-grown trees in most localities, and the presence of considerable quantities of infiltrated materials in the heartwood. When samples of heartwood were leached in cold water for 14 days, their oven-dry weight was reduced as much as 3 per cent, nor could this treatment be supposed to have removed all the infiltrated substances in the wood.

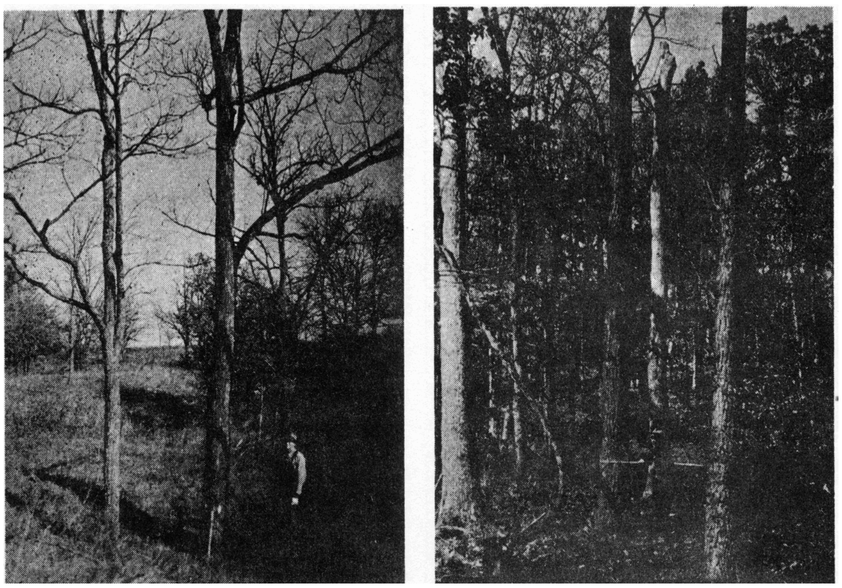

Figure 1 - *Open-grown (left) and forest-grown black walnut in adjacent woodland and pasture, southern Indiana.*

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Table 1.--Locality of origin and distinctive features of environment for black walnut studied

| Shipment No. | Tree No. | Location | Elevation | Topography | Underlying rock formations and soil type | Description of stand |
|---|---|---|---|---|---|---|
| | | | Feet | | | |
| 1565 | 1-5 | Hocking County, Ohio | 850 | Hilly with narrow ravines and steep slopes. | Sandstone and shale rocks covered by glacial drift -- clay loam soil | Open-grown trees with short trunks and large crowns. |
| 1566 | 6-10 | Lawrence County, Indiana | 400+ | Moderate to steep slopes to East Fork of White River. | Upper slope shale and sandstone. Limestone outcrop on lower slope -- clay loam soil. | Walnut trees with long clear trunks in farm woodlot of mixed hardwoods. |
| | 11-15 | | | | | Open-grown trees with wide crowns and short boles; these trees adjacent above woodlot. |
| 1567 | 16-21 | Crawford County, Indiana | ......... | Fairly level creek bottom. | Alluvial soil with gravel deposits. | Moist site hardwoods -- logged 6 years ago. |
| 1567 | 22-26 | Perry County, Indiana | ......... | Short steep slope. Northerly exposure. | Outcrops of limestone. | Heavily cut in the past. Many saplings of mixed hardwood species. |
| 1568 | 27-31 | Fannin County, Georgia | 2,200 | Mountainous, upper slopes steep, lower slopes moderate. | Crystalline rocks, stony loam soil. | Open-grown trees at upper edge of former old field. Moderate slope becoming steep above. Trees have short boles and wide crowns. |
| 1568 | 32-36 | Fannin County, Georgia | 2,200 | Mountainous, upper slopes steep, lower slopes moderate. | Crystalline rocks, stony loam soil. | Forest-grown trees at foot of steep slope on north side of Sids Mountain. Logged 3 years ago for dead chestnut and oak stave bolts. Trees numbered 35 and 36 were much younger than the others of this group. |
| 1569 | 37-41 | Madison County, Arkansas | 1,800 | Mountainous, moderate slopes above rock ledge near Baldwin Creek. | Sandstone-shale rocks. Very stony loam soil. | Old woodlot of mixed hardwoods in which walnut trees have been favored. |
| | 42-46 | | | | | Open-grown walnut trees in pasture adjacent to woodlot. |
| 1570 | 47-51 | Ozark County, Missouri | 800 | Level flood plain below high cliffs. | Limestone region alluvial soil. | River bottom hardwoods culled over for best timber several years ago. |
| 1570 | 52-58 | Douglas County, Missouri | 900 | Small creek valley. | Limestone rocks, gravelly to stony dry soil. | Trees on edges of small openings along creek and among adjacent upland hardwoods. |
| 1570 | 59-60 | Douglas County, Missouri | 1,200 | Summit of broad ridge. | Limestone region, stony clay loam soil. | Open-grown trees along a fence. |
| 1571 | 101-111, 200 | Iowa County, Wisconsin | 1,100 | Steep slopes of narrow ravine. | Driftless area, limestone region, clay loam soil. | Woodlot of mixed hardwoods. |

Although average specific gravity values tended downward as rate of growth declined (Fig. 3), wide fluctuations were present in each growth–rate (rings-per–inch) class. For example, the 6– to 10–rings–per–inch class, in which fell 44 per cent of the specimens tested, included some of the highest and some of the lowest specimens.

## Shrinkage

Radial and tangential shrinkage data were obtained on specimens approximately 1 by 1 by 4 inches in size. Longitudinal shrinkage data were obtained on specimens 9 1/2 inches long 5/8 inch wide in the radial direction, and 1/4 inch thick in the tangential direction. All shrinkage specimens were air–dried to approximately 6 per cent moisture content before final drying in an oven to a moisture free condition.

No significant shrinkage differences were found as between specimens from open–grown and forest–grown black walnut. The minimum volumetric shrinkage from the green to the oven–dry condition was 8 per cent for forest–grown trees and 6.4 per cent for open-grown trees, but average differences were negligible. Average radial, tangential, and longitudinal shrinkage values tallied closely for open–and forest–grown specimens (Fig. 4). Samples from the 8– to 19–foot level in the tree gave average radial shrinkage values of 5.8 per cent and 5.7 per cent, tangential shrinkage values of 8.7 per cent and 8.4 per cent, and longitudinal shrinkage values of 0.21 per cent and 0.25 per cent for open– and forest–grown trees respectively.

Differences in shrinkage values for sapwood and heartwood were somewhat greater than average differences between forest-grown and open–grown stock. For open–grown stock, sapwood specimens gave average volumetric shrinkage values of 15.9 per cent while heartwood specimens averaged only 12.9 per cent (Fig. 6). Similarly, in forest–grown trees, sapwood and heartwood specimens averaged 15.6 and 12.6 per cent, respectively. Samples of mixed sapwood and heartwood were much closer, open–grown averaging 14.0 per cent and forest–grown 13.7 per cent.

No radial shrinkage specimens were cut entirely of sapwood, so that no clear–cut comparison of heartwood and sapwood was made in this shrinkage category. In tangential shrinkage, however, heartwood specimens averaged 8.4 per cent while sapwood specimens averaged 10.4 per cent, with but little

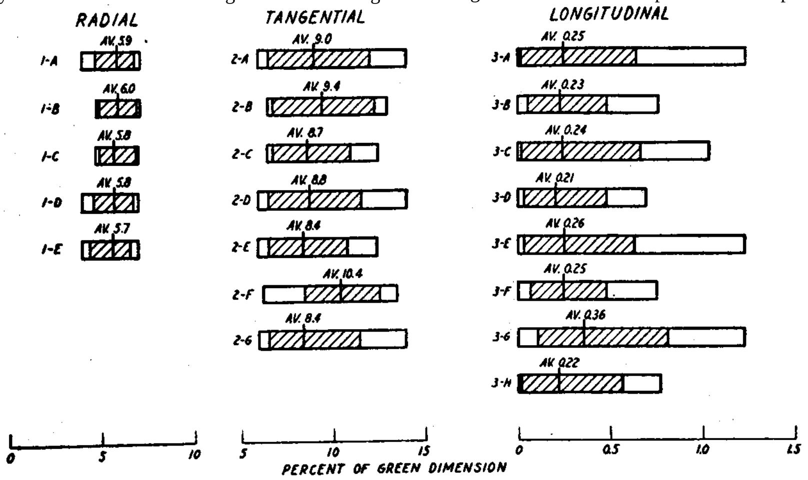


*Figure 4 - Variation in radial, tangential, and longitudinal shrinkage of black walnut.*

(1A) Range in all tree (249 specimens)
(1B) Range in open-grown trees, all heights (82 specimens)
in open-grown trees. 8 to 19-foot height (33 specimens)
(1D) Range in forest-grown trees, all heights (167 specimens)
(1E) Range in forest-grown trees, 3 to 19-foot height (50 specimens)
(2A) Range in all trees (352 specimens)
(2B) Range in open-grown trees, all heights (114 speci-
mens)
(2C) Range in oven-grown trees, 8 to 19-foot height (47 specimens)
(2D) Range in forest-grown trees, all heights (238 specimens)
(2E) Range in forest-grown trees, 8 to 19-foot height (78 specimens)
(2F) Range in sapwood of all trees (119 specimens)
(2G) Range in heartwood of all trees (164 specimens)
Range in all trees (725 specimens)
(3B) Range in all trees at the 8
to 19-foot height (258 specimens)
(3C) Range in open-grown trees. all heights (230 specimens)
(3D) Range in oven-grown trees. 8 to 19-foot height (105 specimens)
(3E) Range in forest–grown trees. all heights (495 specimens)
(3F) Range in forest-grown trees, 8 to 19-foot height (153 specimens)
(3G) Range in sapwood, all trees (145 specimens)
(3H) Range in heartwood, all trees (511 specimens)

*The average value is shown for each group. The shaded portion of each bar represents the middle 90 per cent of the specimens.*

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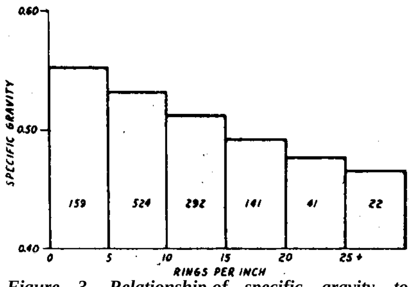


*Figure 3.—Relationship of specific gravity to rate of growth (rings per inch) of all black walnut specimens by growth rate classes. The height of each bar represents the average specific gravity found from tests on the number of specimens indicated in each bar having a ring count falling in the class interval shown at the bottom of each bar. Specific gravity values in this figure are based upon the weight of the specimens when oven dry and their volume when green.*

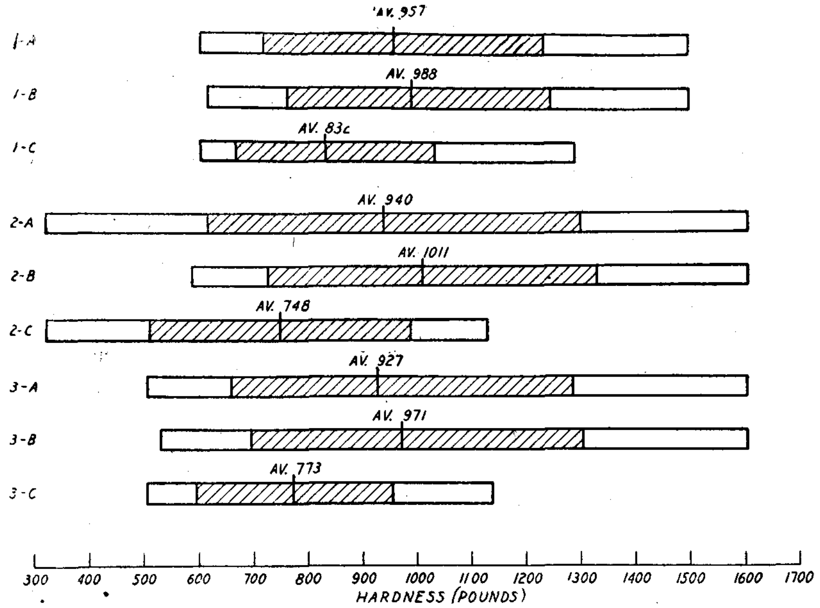


*Figure 5—Variation in hardness. for end, tangential, and radial surfaces and separately for sapwood and heartwood of each surface at all heights in open-grown and forest-grown black walnut trees tested in a green condition*

**End Hardness:**
**(1A) Total range (600 specimens)**
**(1B) Range of heartwood (481 specimens)**
**(1C) Range of sapwood (119 specimens)**
**Tangential Hardness:**
**(PA) Total range (676 specimens)**
**(2B) Range of heartwood (494 specimens)**
**(2C) Range of sapwood (181 specimens)**

**Radial Hardness:**
**(3A) Total range (598 specimens)**
**(3B) Range of heartwood (466 specimens)**
**(3C) Range of sapwood (132 specimens)**

***Load required to embed a 0.444-inch ball to one-half its diameter.**

***The average value is shown for each group. The shaded portion of each bar represents the middle 90 per cent of the specimens.***

difference in the extreme limits of the range for tangential shrinkage between the two portions of the tree. On the other hand, sapwood had by far the higher values for longitudinal shrinkage, averaging 0.36 per cent and with a maximum of 1.23 per cent in contrast to an average of 0.22 per cent and a maximum of 0.78 per cent for heartwood. This difference caused serious crooking in many of the longitudinal shrinkage specimens which contained both heartwood and sapwood.

Manufacturers of black walnut gunstock material stress its low ratio of radial to tangential shrinkage. Former Forest Products Laboratory values put this ratio at 1.0 to 1.36. Average values obtained in the studies here reported, which are based on many more samples, raised this ratio, putting it at 1.0 to 1.50. Maximum radial and tangential values had a ratio of 1.0 to 1.94.

## Straightness of Grain

In neither open- nor forest-grown trees did undue slope of grain, either spiral or the more complex interlocked type, appear to present any serious problem for gunstock production. Splitting tests in material from different heights in 21 forest-grown and 15 open-grown trees showed relatively few samples with a high degree of spiral grain. Only 6 trees, 3 open-grown and 3 forest-grown, revealed a slope of spiral of more than 1 in 10 inches near the stump. At the 8- to 19-foot level, only 3 trees, all forest-grown, had slope of this degree or greater, and at greater heights no slope in excess of 0.8 inch in 10 inches was found. Spiral grain was more severe near the bark than at the pith. Table 3 gives data on slope of grain found in the tests.

**Table 3-Spiral Grain in Black Walnut by Location in Tree**

| Position in Tree | Deviation From the Vertical in a Length of 10 Inches: Forest Grown (Inches) | Open Grown (Inches) |
|---|---|---|
| Near the stump | | |
| Near pith | 0.37 | 0.28 |
| Near bark | .50 | .55 |
| Difference | .13 | .27 |

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| | | |
|---|---|---|
| **8 to 19 feet** | | |
| **Near pith** | **.29** | **.26** |
| **Near bark** | **.44** | **.26** |
| **Difference** | **.15** | **.0** |
| **20 to 31 feet** | | |
| **Near pith** | **.22** | **.32** |
| **Near bark** | **.35** | **.38** |
| **Difference** | **.13** | **.06** |
| **Above 32 feet** | | |
| **Near pith** | **.28** | .... |
| **Near bark** | **.33** | .... |
| **Difference** | **.05** | .... |

Interlocked grain was present just above the stump in 11 trees. This is a type of growth in which the fibers are inclined in one direction in a number of rings of annual growth, then gradually reverse and are inclined in the opposite direction in succeeding growth layers, en reverse again. At the 8- to 19-foot level, 3 forest-grown and 2 open-grown trees showed a reversal in direction of spiral from near the center to the bark side. At greater heights only 1 tree, forest-grown, showed a reversal in spiral.

## Crook

Tests of specimens containing approximately half sapwood and half heartwood demonstrated that gunstocks manufactured of both heartwood and sapwood at a moisture content of 7 to 8 per cent may be expected to develop crook when exposed to high humidities. Of 51 such specimens, which were 9% inches long and 1/4 inch by 5/8 inch in cross section, 44 developed crook ranging from 0.02 to 0.20 inch at the center and averaging 0.067 inch when dried from the green to the oven-dry condition. To determine how much these crooked specimens would straighten under conditions which would cause them to re-absorb moisture, they were laced in a humidity room and subjected for 4 months to 80 per cent relative humidity and 80 degrees F. At the end of that time the average deflection for all had decreased to 0.045 inch, a reduction of nearly 33 per cent, but 10 remained unchanged.

Further to illustrate the tendency in heartwood-sapwood pieces to crook when exposed to changing moisture conditions, a piece 2 by 2 1/4 inches by 4 feet was cut from the edge of a plank which had crooked during kiln-drying. The crook in this piece was 0.3 inch at the middle of the sap face. Planed straight on the heart side, this piece was exposed for 6 months to 80 degrees F. and 80 per cent relative humidity. At the end of that time, the sap face crook had been reduced to 0.2 inch but the heart face had crooked 0.1 inch, he amount lost by the sap face.

## Hardness

Hardness is particularly important in woods which are continuously subjected to surface wear and indentation. Gunstocks in military use may be considered to require such a property in fairly high degree. On the other hand, since hardness varies closely with specific gravity and, therefore, with weight, a reasonable compromise between hardness and weight requirements must be made if the over-all weight of a gun is to be kept as low as possible. Experience would seem to indicate that black walnut offers such a desirable combination of weight and wearing qualities. Hardness is measured by the force required

Table 2.--Range in ages and diameters and average rings per inch and specific graviety values of heartwood and sapwood at different heights in trees and average for tree group representing different black walnut stands

| Tree Nos. | Range in ages | Range in diameter breast height | Height in tree | Heartwood (100 percent): Number of tests | Rings per inch | Specific gravity | Sapwood (Over 90 percent): Number of tests | Rings per inch | Specific gravity | Mixed heartwood and sapwood: Number of tests | Rings per inch | Specific gravity | Average at given height: Number of tests | Rings per inch | Specific gravity | Average by group: Total number of tests | Rings per inch | Specific gravity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Years | Inches | Feet | | | | | | | | | | | | | | | |
| 1-5 | 57-72 | 10-20 | 1-2 | 26 | 7.3 | 0.578 | | | | 10 | 20.0 | 0.472 | 36 | 10.8 | 0.549 | | | |
| | | | 9-19 | 30 | 7.6 | .562 | 4 | 19.5 | 0.482 | 16 | 15.2 | .497 | 50 | 11.0 | .529 | | | |
| | | | 24 | 4 | 9.5 | .549 | | | | 4 | 21.0 | .496 | 8 | 15.2 | .522 | 94 | 11.3 | 0.536 |
| 6-10 | 91-104 | 16-20 | 1-2 | 24 | 9.7 | .518 | 2 | 14.5 | .479 | 8 | 16.0 | .468 | 34 | 11.5 | .504 | | | |
| | | | 12-16 | 22 | 9.5 | .488 | | | | 10 | 22.1 | .459 | 32 | 13.4 | .479 | | | |
| | | | 26-46 | 26 | 9.8 | .513 | 4 | 19.8 | .487 | 12 | 22.8 | .470 | 42 | 14.5 | .498 | 108 | 13.2 | .494 |
| 11-15 | 48-76 | 14-18 | 1-2 | 25 | 7.6 | .587 | 1 | 28.0 | .424 | 9 | 16.1 | .527 | 35 | 10.4 | .567 | | | |
| | | | 10-12 | 21 | 8.2 | .565 | 4 | 21.0 | .468 | 12 | 15.3 | .521 | 37 | 11.9 | .540 | | | |
| | | | 24-27 | 6 | 9.2 | .572 | | | | 6 | 17.2 | .540 | 12 | 13.2 | .556 | 84 | 11.5 | .553 |
| 16-21 | 64-90 | 13-18 | 1-5 | 24 | 10.5 | .542 | 3 | 14.3 | .516 | 9 | 13.4 | .491 | 36 | 11.6 | .527 | | | |
| | | | 12-14 | 21 | 10.1 | .501 | 4 | 16.5 | .501 | 9 | 14.9 | .480 | 34 | 12.1 | .495 | | | |
| | | | 22-36 | 22 | 9.7 | .517 | 3 | 23.0 | .460 | 13 | 15.4 | .498 | 38 | 12.7 | .506 | 108 | 12.1 | .510 |
| 22-26 | 63-94 | 11-16 | 1-2 | 16 | 11.1 | .562 | 4 | 14.0 | .523 | 8 | 11.5 | .547 | 28 | 11.6 | .546 | | | |
| | | | 12-14 | 16 | 11.6 | .514 | 5 | 15.0 | .505 | 5 | 15.2 | .529 | 26 | 13.0 | .515 | | | |
| | | | 23-25 | 11 | 10.5 | .519 | 2 | 17.5 | .495 | 9 | 14.2 | .534 | 22 | 12.7 | .523 | 76 | 12.4 | .529 |
| 27-31 | 32-54 | 13-18 | 1-3 | 22 | 4.7 | .556 | 7 | 9.9 | .508 | 2 | 12.5 | .490 | 31 | 6.4 | .541 | | | |
| | | | 10-18 | 23 | 4.5 | .520 | 6 | 11.2 | .477 | 7 | 8.9 | .505 | 36 | 6.5 | .510 | | | |
| | | | 20-24 | 10 | 4.7 | .546 | 3 | 9.0 | .511 | 5 | 8.2 | .502 | 18 | 6.4 | .528 | 85 | 6.4 | .525 |
| 32-34 | 104-120+ | 17-22 | 2-7 | 9 | 15.7 | .475 | | | | 4 | 25.5 | .436 | 13 | 18.7 | .463 | | | |
| | | | 15-16 | 10 | 15.2 | .468 | | | | 4 | 23.0 | .448 | 14 | 17.4 | .462 | | | |
| | | | 20-62 | 28 | 14.0 | .513 | 1 | 27.0 | .479 | 13 | 24.1 | .465 | 42 | 17.5 | .497 | | | |
| 35-36 | 42-45 | 10-11 | 1 | 7 | 6.6 | .580 | 3 | 13.0 | .518 | 2 | 16.0 | .560 | 12 | 9.8 | .559 | | | |
| | | | 9-14 | 4 | 5.8 | .520 | | | | 4 | 18.0 | .489 | 8 | 11.9 | .504 | | | |
| | | | 20-29 | 4 | 7.8 | .534 | 2 | 18.5 | .492 | 2 | 17.5 | .517 | 8 | 12.9 | .519 | 97 | 15.8 | .498 |
| 37-41 | 53-55 | 12-18 | 1 | 26 | 6.7 | .576 | 4 | 12.2 | .492 | 7 | 12.6 | .538 | 37 | 8.4 | .560 | | | |
| | | | 12-19 | 20 | 7.6 | .526 | 1 | 18.0 | .494 | 9 | 14.6 | .504 | 30 | 10.0 | .518 | | | |
| | | | 23-34 | 19 | 7.5 | .553 | 4 | 18.0 | .524 | 6 | 14.3 | .506 | 29 | 10.3 | .539 | 96 | 9.5 | .540 |
| 42-46 | 45-68 | 12-16 | 1-2 | 21 | 7.4 | .622 | 4 | 12.2 | .552 | 6 | 11.0 | .560 | 31 | 8.7 | .601 | | | |
| | | | 10-16 | 18 | 7.8 | .566 | 4 | 13.0 | .535 | 8 | 12.5 | .556 | 30 | 9.7 | .559 | | | |
| | | | 20-25 | 10 | 7.4 | .574 | 4 | 13.5 | .547 | 4 | 17.5 | .538 | 18 | 11.0 | .560 | 79 | 9.6 | .576 |
| 47-51 | 43-72 | 11-14 | 1-2 | 20 | 8.2 | .518 | 8 | 11.8 | .478 | 2 | 17.0 | .460 | 30 | 9.6 | .503 | | | |
| | | | 12-15 | 14 | 9.6 | .470 | 6 | 15.2 | .456 | 2 | 11.5 | .470 | 22 | 11.3 | .466 | | | |
| | | | 21-40 | 22 | 7.6 | .492 | 8 | 16.9 | .436 | 6 | 11.0 | .483 | 36 | 10.2 | .478 | 88 | 10.3 | .484 |
| 52-58 | 41-93 | 12-24 | 1-5 | 35 | 8.9 | .535 | 11 | 11.6 | .477 | 4 | 10.5 | .506 | 50 | 9.6 | .520 | | | |
| | | | 6-18 | 33 | 9.7 | .522 | 13 | 13.4 | .461 | 2 | 9.5 | .504 | 48 | 10.7 | .505 | | | |
| | | | 21-29 | 17 | 10.1 | .539 | 7 | 11.6 | .495 | 6 | 10.5 | .488 | 30 | 10.5 | .518 | 128 | 10.2 | .514 |
| 59-60 | 46-48 | 15-16 | 1 | 16 | 4.7 | .584 | 6 | 8.0 | .518 | | | | 22 | 5.6 | .566 | | | |
| | | | 7-17 | 8 | 6.4 | .539 | 1 | 12.0 | .523 | 5 | 10.6 | .509 | 14 | 8.3 | .527 | 36 | 6.6 | .551 |
| 101 + | 26-70 | 10-16 | 1-2 | 40 | 6.6 | .539 | 9 | 8.4 | .514 | 9 | 10.9 | .507 | 58 | 7.5 | .530 | | | |
| | | | 9-12 | 26 | 7.2 | .514 | 7 | 9.4 | .498 | 9 | 9.9 | .495 | 42 | 6.11 | .509 | 100 | 7.8 | .520 |

1Specific gravity values in this table are based upon the weight of the specimens when oven dry and their volume when green.

to imbed a 0.444-inch ball to one-half its diameter.

Hardness values on all surfaces — end, tangential, and radial — including both sapwood and heartwood, averaged somewhat higher for the open-grown material than for that from forest-grown trees, as shown in Table 4 and Figure 5. The heartwood of open-grown trees averaged 14 per cent higher in hardness for all surfaces than did heartwood of forest-grown material, white sapwood of open-grown trees was 8 per cent harder than that of forest-grown stock at the 8- to 19-foot level.

**Table 4—Average Values for Hardness Tests on Three Surfaces of Green Material at the 8- to 19-Foot Level**

| Material | End (Pounds) | Tangential (Pounds) | Radial (Pounds) |
|---|---|---|---|
| **Forest-grown trees** | | | |
| Average | 899 | 853 | 844 |
| Heartwood average | 918 | 901 | 880 |
| Sapwood average | 821 | 731 | 719 |
| **Open-grown trees** | | | |
| Average | 1,005 | 969 | 961 |
| Heartwood average | 1,038 | 1,040 | 1,003 |
| Sapwood average | 881 | 778 | 801 |

Sapwood in general had strikingly lower hardness values than heartwood, averaging 16 per cent lower in end hardness, 26 per cent in tangential hardness, and 20 per cent radially than the average for forest- and open-grown trees combined (Fig. 5). As in the case of specific gravity, the large differences could be accounted for partly by the slower growth of the sapwood portions of the trees and, presumably, in part by the presence of infiltrated materials in the heartwood. These infiltrated materials appear to increase hardness of heartwood more in the green condition (in which these specimens were tested) than in the dry condition, as is shown by previous tests of green and air-dry. black walnut.

## Sapwood Thickness

Although sapwood is but a small art of the diameter of a black walnut log, it finds its way into gunstocks because of the common practice of cutting the stock blanks from the clear wood close to the edges of the flitches; for this reason, a high proportion of the blanks, especially the longer ones, contains more or less sapwood. Since sapwood and heartwood differ in their physical properties, notably in degree of shrinkage, warping may result in drying and some blanks will be rejected for distortion.

In the trees studied, sapwood thickness at the stump averaged 1.15 inches; at all other heights, the average was between 0.90 and 1 inch (Fig. 6). The total range in sapwood thickness was from a low of 0.25 inch to 2.22 inches, varying only slightly as between open- and forest-grown trees.

## Moisture Content

Moisture content determinations were made on the green black walnut samples (which had been end-coated with hardened gloss oil the same day the trees were felled to retard moisture loss in shipment) to establish data on the amount of moisture contained in the standing tree.

Green moisture content varied more widely for forest-grown than for open-grown material. Open-grown heartwood ranged from 70 to 93 per cent in moisture content, while forest-grown heartwood ranged from 65 to 100 per cent. open-grown sapwood moisture content varied only 78 to 88 per cent, while that of forest-grown trees spread from 84 to 91 per cent. Both sapwood and heartwood from the lower parts of the trees, especially near the stumps, gave higher moisture content values than that from the upper portions, whether open- or forest-grown. Figure 6 summarizes respective average values for moisture content, specific gravity, shrinkage in volume, and radial measurements of sapwood at different locations in the tree.

[1]See United States Department of Agriculture Technical Bulletin 479, "Strength and Related Properties of Woods Grown in the United States," obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 35 cents per copy.

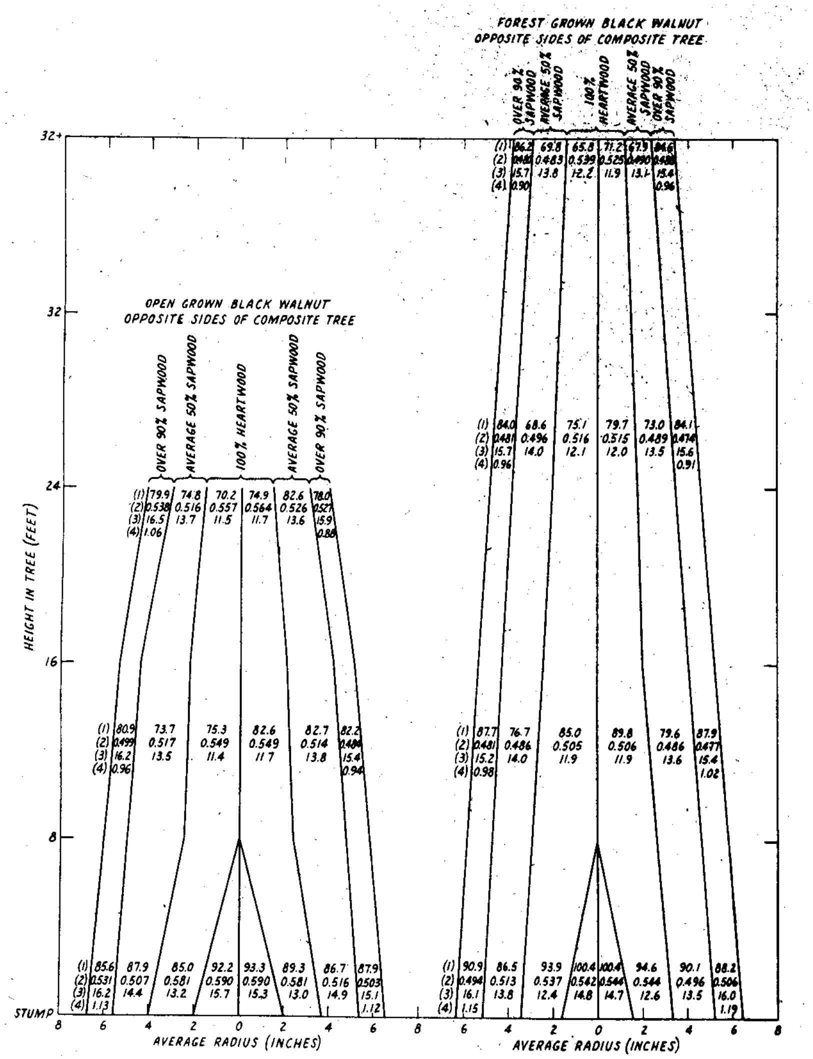


*Figure 6 - Composite diagrams of open-grown and forest-grown walnut trees with average valuer for (1) moisture content (per cent), (2) specific gravity (based on weight when oven dry and volume when green), (3) shrinkage in volume (per cent), and (4) width of sapwood in inches at the respective heights and positions in the cross section.*

## Summary

Open-grown black walnut, on the basis of the sample trees studied, was heavier, harder, and had less variation in green moisture content than did forest-grown material. No significant differences in shrinkage nor in the presence of undue slope of grain were found in the two categories; each had about the same proportion of sapwood to heartwood.

The heartwood averaged considerably heavier than sapwood. The heaviest wood was found in the lower portions of open-grown trees. Specific gravity was lower in the narrower-ringed samples. On the whole, the black walnut samples had a relatively high range of specific gravity.

Nearly all longitudinal shrinkage specimens containing both heartwood and sapwood crooked during drying, becoming concave on the sapwood side. This crook was reduced about one-half upon subsequent exposure to a relative humidity of 80 per cent.

Although hardness values for end, tangential, and radial surfaces, respectively, varied widely, average values for the three surfaces were nearly equal. Sapwood hardness for all surfaces combined averaged more than 20 per cent lower than that of heartwood.

Ratios of average heartwood-sapwood values of the several tests were:

| Property | Ratio Heart to Sap |
|---|---|
| **Specific gravity:** | |
| Open-grown trees | 1.0 to 0.89 |
| Forest-grown trees | 1.0 to 0.94 |
| **Shrinkage:** | |
| In volume | 1.0 to 1.23 |
| Tangential | 1.0 to 1.24 |
| Longitudinal | 1.0 to 1.63 |
| **Hardness (green):** | |
| End | 1.0 to 0.84 |
| Tangential | 1.0 to 0.74 |
| Radial | 1.0 to 0.80 |

Moisture content was greater in both heartwood and sapwood near the base of the tree, with that in the heartwood greater than that in the sapwood near the base. In the upper portions of the tree, however, the sapwood contained more moisture than did the heartwood

## Conclusions

Weight specifications for black walnut gun stock blanks that eliminate material from near the lower and upper limits of the specific gravity range would result in more uniform gunstock quality. Such specifications could eliminate much low-density sapwood which, when in combination with the heavier heartwood, appears to contribute rather seriously to warping during drying. Since the material having a specific gravity of 0.63 or higher was found only in the thicker ends of butt logs from open-grown trees, such material could be largely eliminated in the selection of logs.



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