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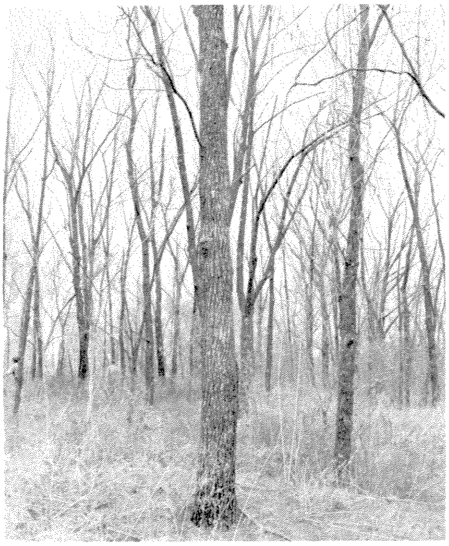

Black Walnut on Kansas Strip Mine Spoils: Some Observations 25 Years after Pruning

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ABSTRACT

Dissections of 14 slow-growing black walnut trees on a strip-mine site revealed that bands of discolored heartwood were associated with pruned and nonpruned branch stubs. Ring shakes were associated with a few pruned and nonpruned stubs, especially with groups of stubs at the same position on the stem. The advantage of early pruning was that even the defects that developed were compartmentalized within the small non-merchantable central core that was the diameter of the tree at the time of pruning.

THIS PAPER reports some observations on the internal condition of wood associated with pruned and nonpruned branch stubs on black walnut trees (*Juglans nigra* L.) 25 years after treatment. The trees were located on a partially graded coal-mine area in southeastern Kansas near Pittsburg. This study was initiated by F. Bryan Clark in 1950, and has been maintained since by Nelson F. Rogers.

Black walnut

Black walnut is one of our most valuable timber trees. Its value depends on many factors, but one of the most important is the amount of defect-free wood in the stem.

Dead branches, large, live, low branches, and poorly closed branch stubs are major causes of defect and the short lengths of clear wood that greatly reduce the quality and value of this tree. It seems that proper pruning early in the life of the tree might increase the quality of black walnut.

The original study in 1950

In January 1950, 720 black walnut trees grown from locally collected seed that had been planted by the Civilian Conservation Corps during the winter of 1935-1936 were pruned to 25, 50, or 75 percent of live crown, or were not pruned. The trees were part of a 2,000-acre planting of pure black walnut. At the time of pruning, the 14-year-old trees were 4 to 6 m in height, and 8 to 15 cm in diameter at breast height (dbh). The site is poor for the growth of black walnut (Geyer 1971). Additional details on the area (Rogers 1951; Geyer and Naughton 1971; Geyer and Rogers 1972; Geyer 1972) and on the study after 5 and 10 years (Clark 1955; Clark and Seidel 1961) have been published.

Dissection of trees in 1976

In April 1976, 14 trees considered representative of fast-growing and slow-growing specimens on the site were dissected with a chainsaw. We wanted to determine the internal condition of the wood associated with pruned and nonpruned branch stubs, basal seams, and mechanical wounds. The trees were located approximately 5 miles west of Pittsburg. Eight of these 14 trees (including 2 nonpruned trees) had been part of the initial study by Clark (Clark and Seidel 1961) (Table 1); the remaining 6 trees were not pruned and were cut as controls. On the study trees, the pruned stubs were dissected radially with a chainsaw or were split with an ax. The same procedure was followed for most of the stubs on the control trees.

Although only 14 trees were dissected, this sample was considered representative because more than 10,000 trees with similar defects have been dissected over a 17-year period (Shigo and Larson 1969; Shigo 1975, 1976; Solomon and Shigo 1976).

Table 1.—Increases in diameter and height growth from 1950 to 1976 for dissected black walnut trees near Pittsburg, Kansas

Tree number	Percentage of live crown removed	Dbh		Height	
		January 1950	April 1976	January 1950	April 1976
		cm		*m*	
359	75	14	29	7	14
358	75	10	22	6	12
352	0	13	24	8	14
346	0	8	17	7	13
338	50	13	20	7	12
314	75	14	22	9	13
82	75	12	20	7	12
340	75	14	17	8	11

Observations after 25 years

A few trees were more than 40 cm in dbh; this indicates that some trees were able to grow rapidly on the better areas of this poor site. Most of the trees were much smaller. Heavy, low, dead branches, and large, low, living branches were common on most nonpruned trees (Fig. 1), but there were several nonpruned trees that had large sections of clear stem with well-closed branch stubs (Fig. 2). This indicates that a few trees will produce fair-quality wood without treatment on a poor site.

Large bumps or callus mounds were common around nonpruned stubs (Fig. 3). Dissections showed that discolored heartwood was associated with these stubs (Fig. 4). A dark fluid oozed from a few stubs (Fig. 5); this was a sign of wetwood and discolored heartwood.

Cavities behind many partially closed stubs were inhabited by ants (Fig. 6); ants also were active on stubs during the dissections.

Tree 340 grew slowly after pruning (Figs. 7 and 8), while Tree 359 continued to grow fairly rapidly (Fig. 9) (Table 1). The trees were approximately the same diameter at the time of pruning, and they were both pruned to 75% of live crown (Table 1). The pruning wounds were still open on Tree 340 (Fig. 8), but all of the pruning wounds on the faster growing tree had closed (Fig. 10).

Dissections showed that the stubs were sound and were covered by sound wood in the faster growing trees (Fig. 11). But dark bands of wood were associated with wounds even in the fastest growing trees whose stubs had closed rapidly (Fig. 12). These bands were in the sapwood rings that had been formed just before pruning (Figs. 12 and 13). The darkest band was in the youngest growth ring that was present at the time of wounding. The ring that formed after pruning (the 1950 growth ring) was a different color.

After some branch samples were dried in the laboratory, a separation began to develop between the 1949 and the 1950 growth rings (Fig. 14). This separation was the most pronounced in samples that had several pruned stubs at approximately the same positions (Fig. 15). In the field we were able to pull apart these samples because areas of ring shake had already formed in the living tree—this was the case with pruned and nonpruned stubs.

The dark band associated with the 1949 growth ring was obvious several meters above and below the pruned stubs (Fig. 16).

Bands of dark wood were also associated with mechanical wounds. Some trees were wounded when they were very young. It appeared that some of the wounds were caused by fire, because charcoal was present within the wound. It is also possible that some of the wounds were caused by the sunscald that occurred after the 1954 growing season and before the 1955 season (Clark 1961). Regardless, many trees had basal seams associated with wounds (Fig. 17).

A dark fluid flowed from some of the seams. Dissections showed that the primary seam was associated with the inrolled callus around the original wound, but that other seams were associated with cracks that formed from the inside and developed outward (Figs. 18 and 19). When decay was associated with these wounds, it was confined to the tissues present at the time of wounding. Decay associated with stubs was also confined to the tissues present at the time the branch died (Fig. 20).

Discussions

The benefits of pruning were obvious in most trees. Pruning increased the lengths of clear wood, and sound clear wood covered the stubs on the fast growing trees. Observations by Clark (1961) 10 years after pruning indicated that most pruning wounds had closed. A few were still open on the slow-growing trees. Some of the pruning wounds on Tree 340, a slow-growing tree, were still open 25 years after pruning. Wound closure is associated with growth rate (Neely 1970), and wounds on slow-growing trees do not close rapidly. But wound closure is a minor part of the wound response. Wounds close on the outside and compartmentalize on the inside. It is the inside compartmentalization, rather than the external closure, that is most important (Shigo et al. 1977a, 1977b).

The internal condition of the wood associated with the stubs and wounds on the 14 dissected trees did not differ from that of thousands of others dissected over a 17-year period. The results of these studies have helped in developing a concept of compartmentalization of decay in trees (Shigo 1975, 1976); that is, a tree is a compartmented plant, and that after wounding, its defense system is geared to minimizing the number of compartments that are infected. After wounding, the injured cambium begins to form new tissue—the barrier zone (Sharon 1973). McGinnes (1975) has described this zone in black walnut. The barrier zone confines the infection to the tissues present at the time of wounding, and new tissues that form are not infected. The barrier zone was obvious in the pruned and nonpruned dissected samples. The dark band of wood was on the pith side of the barrier zone, and it extended for great distances above and below the wounds.

The barrier zone was also the site of ring shakes; this was shown by McGinnes (1975) for black walnut. Ring shakes are associated with wounds (McGinnes et al. 1971, 1974a, 1974b; Shigo 1972), but not all wounds form ring shakes. Ring shakes are important defects in black walnut (McGinnes 1968, 1975; McGinnes and Shigo 1975).

The results of the dissections of the stubs suggest that care should be taken not to remove too many branches from one location on the stem during one pruning period. This agrees with the recommendation by Clark (1955, 1961).

In addition to the possibility of ring shakes forming after the pruning of branch clusters, the bands of dark wood could also be defects (McGinnes 1975). Color and patterns of color are important factors in determining the quality and value of black walnut (Moslemi 1967; Nelson et al. 1969; Maeglin and Nelson 1970).

It may be that the most recently formed rings of sapwood are altered in some way at the time of pruning; this altered wood may later develop darker pigments as it is transformed into heartwood. Or the formation of heartwood may be stalled by the wounds, as it is in white oak (McGinnes and Shigo 1975). Infection of the sapwood exposed by the pruning wound may also affect subsequent pigmentation. Regardless of the exact cause, the black bands were associated with the stubs even at some distance above and below the wounds. This helps explain the bands of differently colored heartwood that are common characteristics of black walnut, especially in slow-growing trees on poor sites. The intensity of the bands could reflect a tree's history of branch stubs, and an individual tree's response to branch stub wounds or to other injuries to the wood (McGinnes 1975).

The basal seams were caused by wounds; these seams are often called "frost cracks". The anatomy of these defects was clarified by McGinnes et al. (1976); the seams start from the inside and develop outward.

Great caution must be taken in interpreting these results because the trees are growing on a very poor site. Results of these dissections and the dissections of thousands of other trees indicate that all trees respond to wounds in a similar way—a barrier zone is formed and the tissues along the zone are discolored. But the intensity of the response and the extent of defects associated with it depend on many factors.

The adverse conditions under which the black walnut trees in this study were growing could have had a strong effect on the intensity and the extent of defects associated with the branch stubs.

In conclusion, pruning is not a "cure all" for black walnut. It may be highly beneficial for some trees, but pruning may cause only more problems for others.

Proper pruning at an early age still offers the potential advantage of producing longer lengths of clear wood. Pruning also may result in ring shakes, and in bands of dark heartwood in the small nonmerchantable central core.

A possible solution may be selecting for growth those trees that respond effectively to pruning wounds. Results of recent research suggest that the wound response is under genetic control (Shigo et al. 1977a, 1977b). Some trees of the same species respond to wounds more effectively than others; this was obvious with the trees dissected on the mine spoils. If trees that have a strong response to wounds are pruned, the internal defects will be slight. And even the defects that do develop will be compartmentalized in the small central core that was the diameter of the tree at the time of pruning.

Research indicates that the potential is great for growing high-quality black walnut trees on poor sites such as strip-mine spoils. This can be done through studies on genetics and compartmentalization.

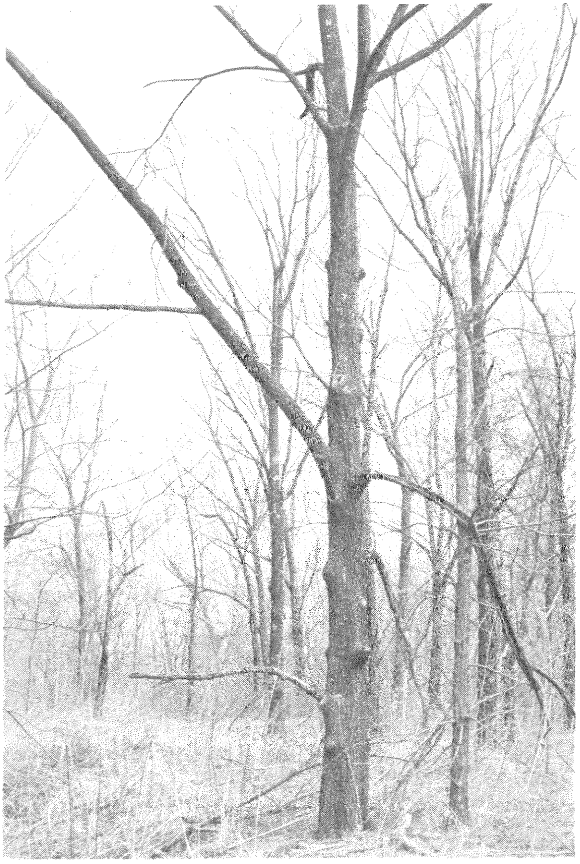


Figure 1.—Fast-growing nonpruned black walnut with many dead branches, poorly closed branch stubs, and large, low living branches.

Figure 2.—Medium growing nonpruned black walnut with well-closed branch stubs, and a long section of clear stem.

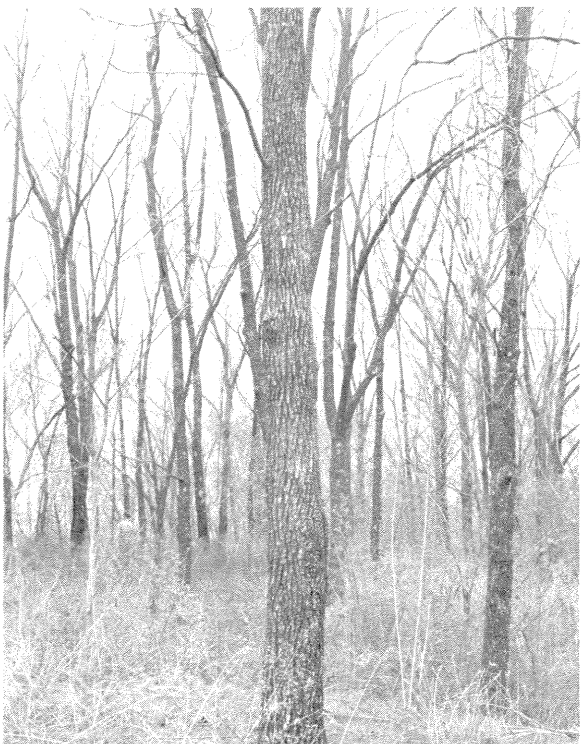


Figure 3.—Large bumps or callus mounds around poorly closed nonpruned branch stubs.

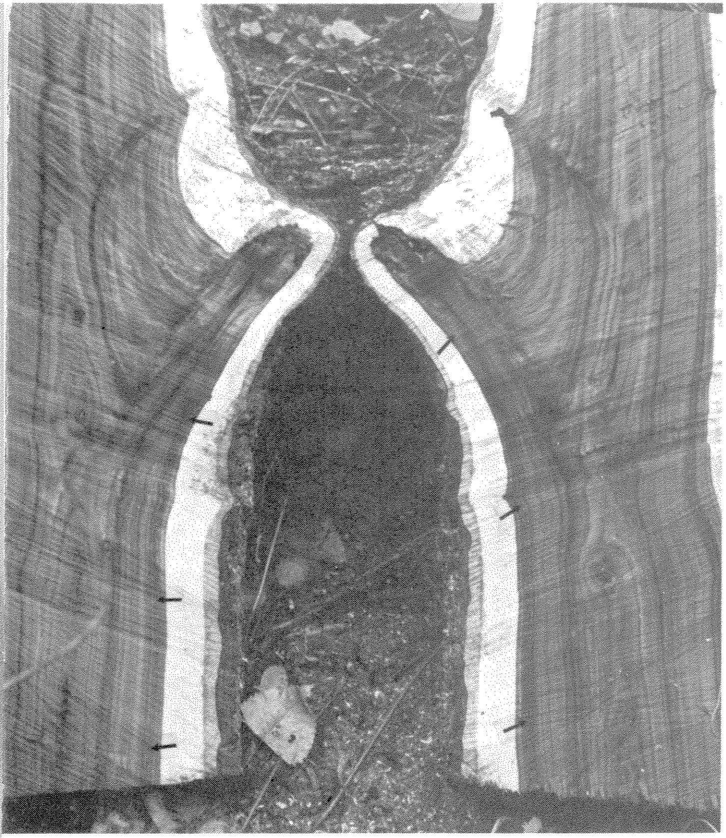


Figure 4.—Dissection of stub shown in Figure 3 (left hand of person). Note dark band of discolored heartwood associated with stub (arrows).

Figure 5.—Dark fluid flowing from an stub indicates internal wetwood and d discolored heartwood.

Figure 6.—Cavities behind swollen stubs inhabited by ants; this was common in many nonpruned trees.

Figure 7.—These trees (large tree: 359; small tree: 340) were approximately the same diameter when both were pruned to 75% of live crown.

Figure 8.—Tree 340 grew slowly after pruning. It still had some open stubs after 25 years (arrows).

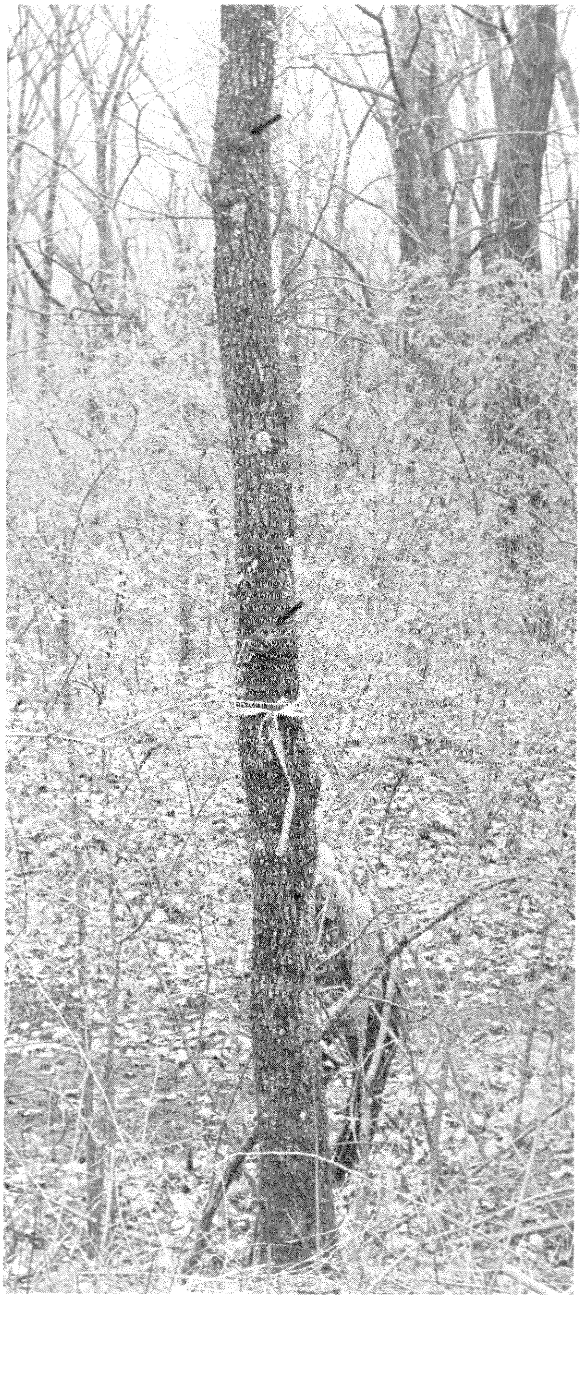


Figure 9.—Tree 359 was a fast-growing tree that had well-closed pruned stubs. The arrow shows the lowest live branch that was present after pruning (see Figure 15 for dissection of this branch).

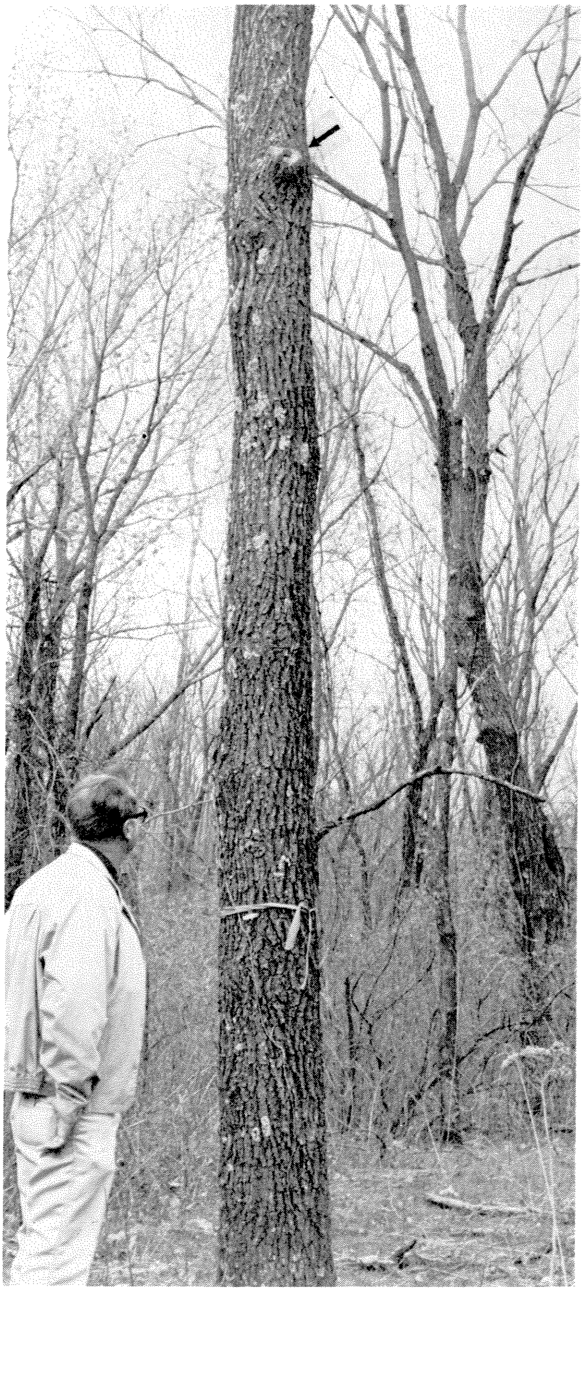


Figure 10.—Well-closed pruning wounds on Tree 359.

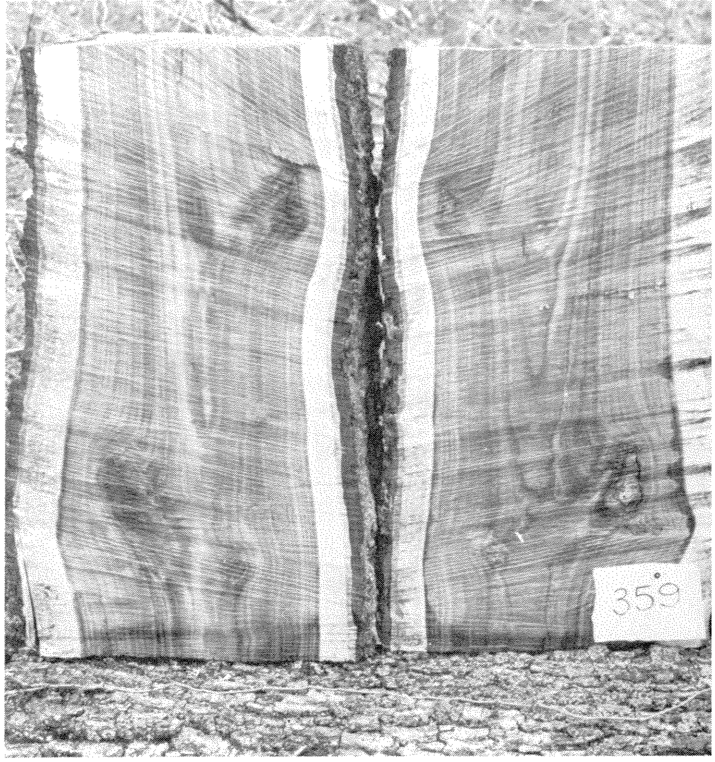


Figure 11.—Dissection of stubs shown in Figure 10; clear wood covered the stubs.

Figure 12.—Arrows point to the diameter of Tree 359 at the time of pruning. Note the dark band of heartwood that formed in the tissues present at the time of pruning.

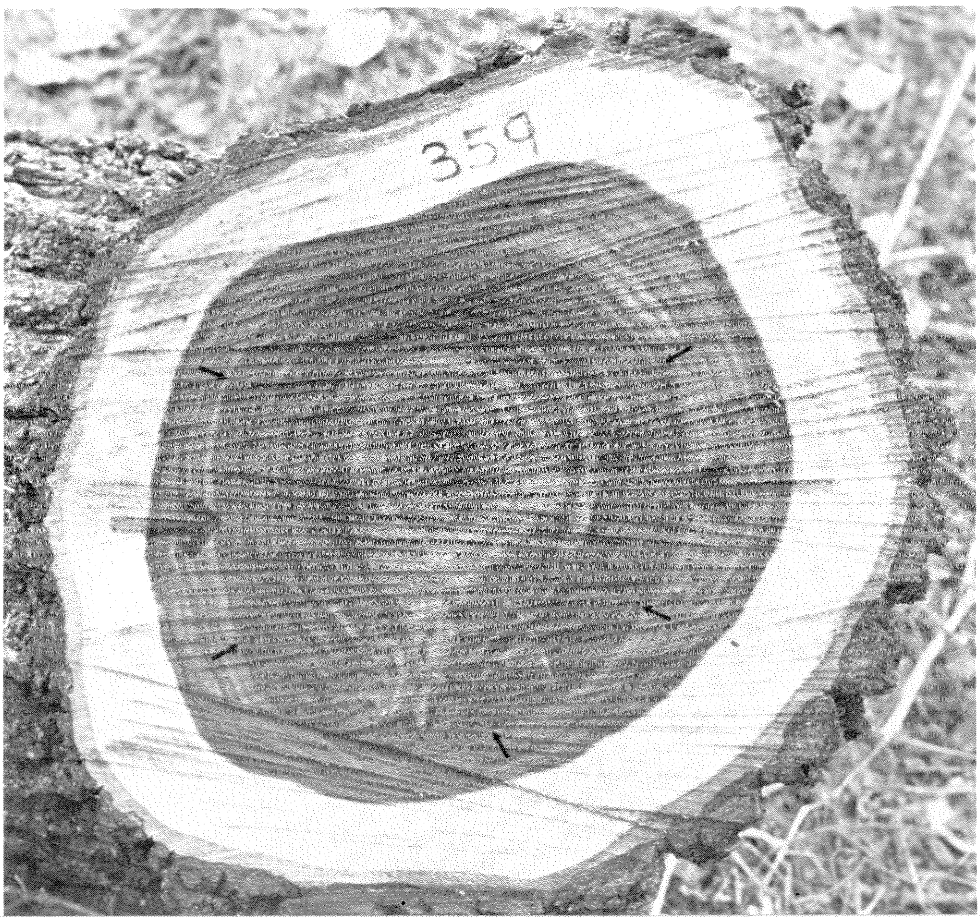


Figure 13.—Dark bands of heartwood were associated with the closed stubs (arrows 1). The central dark core indicates the diameter of the tree when it was wounded at the base early in its life (arrows 2).

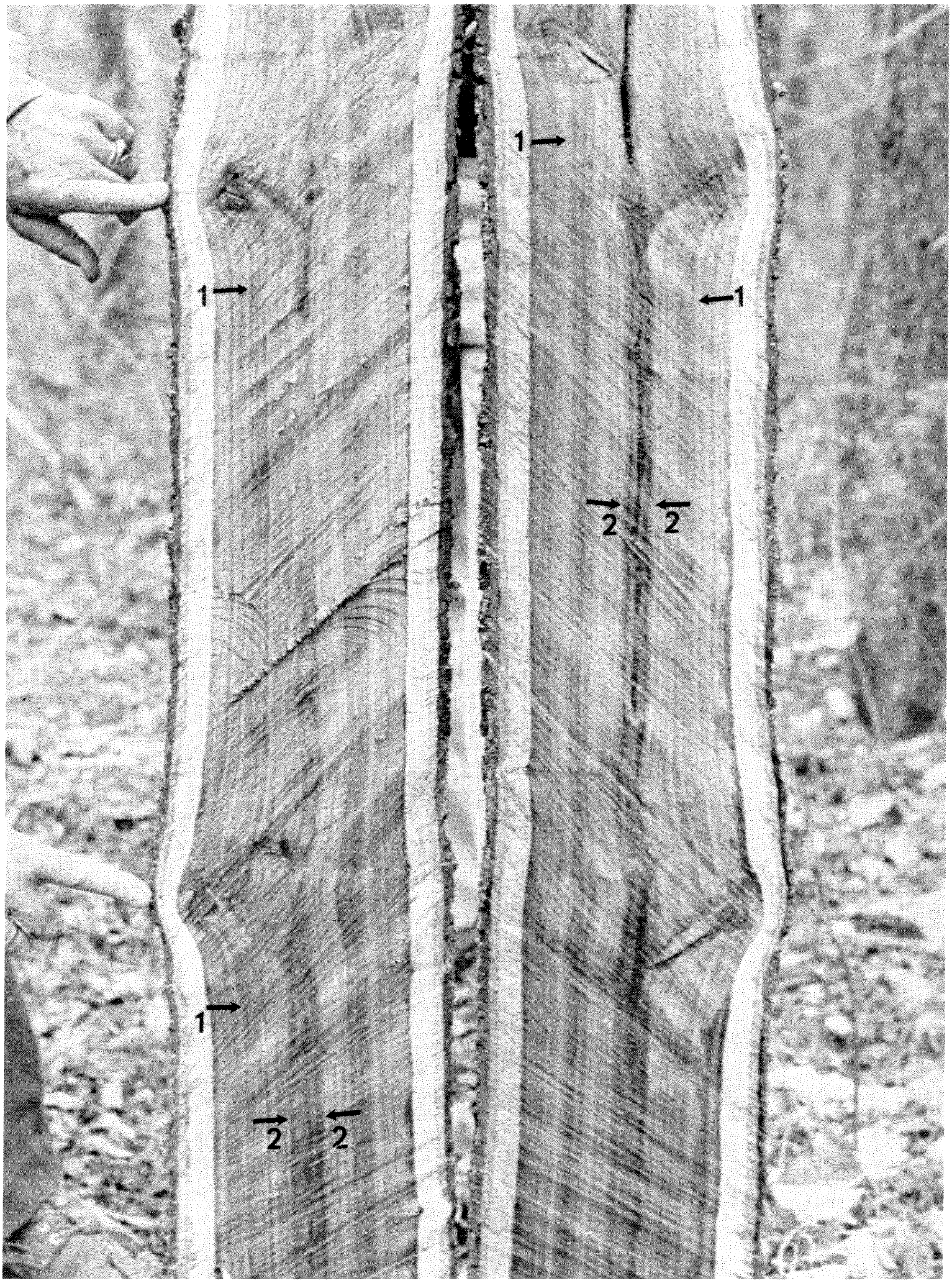


Figure 14.—Closeup of well-closed pruned stub in Tree 359. Note ring shake line at the barrier zone, and band of dark heartwood (arrows).

Figure 15.—Ring shake associated with pruned stub.

Figure 16.—Dissection of non-pruned stub on pruned Tree 359. Note dark lines that indicate diameter of tree when pruned below (arrows 1), and line associated with the non-pruned stub shown here (arrows 2). Note small ant galleries and light-colored decay in stub.

Figure 17.—Basal seams with dark exudate; often incorrectly called "frost cracks", basal seams actually are wound cracks.

Figure 18.—Dissection of tree shown in Figure 17. Note the dark line formed at the time of wounding (arrow). The cracks start from the inside and develop outward as the temperature decreases and shrinks the diameter of the tree.

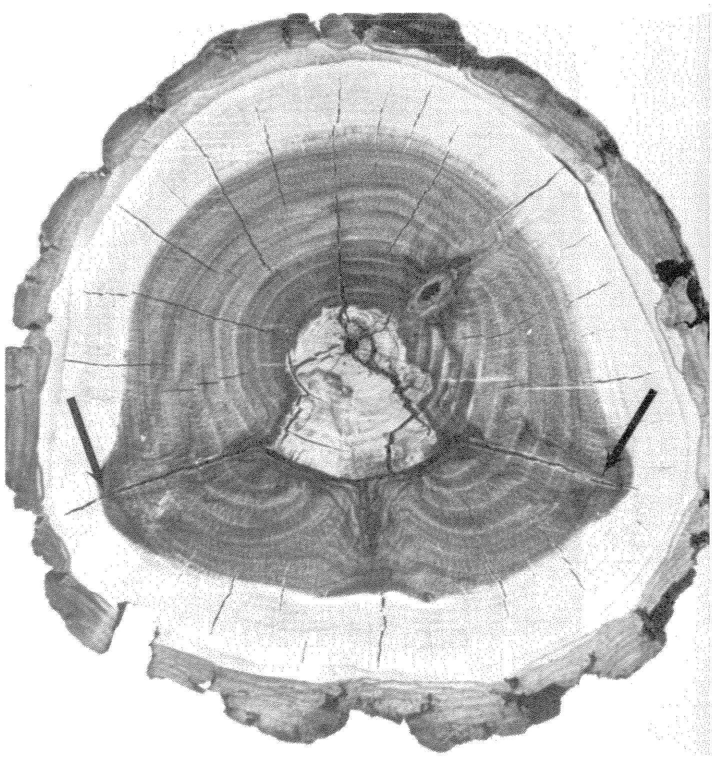
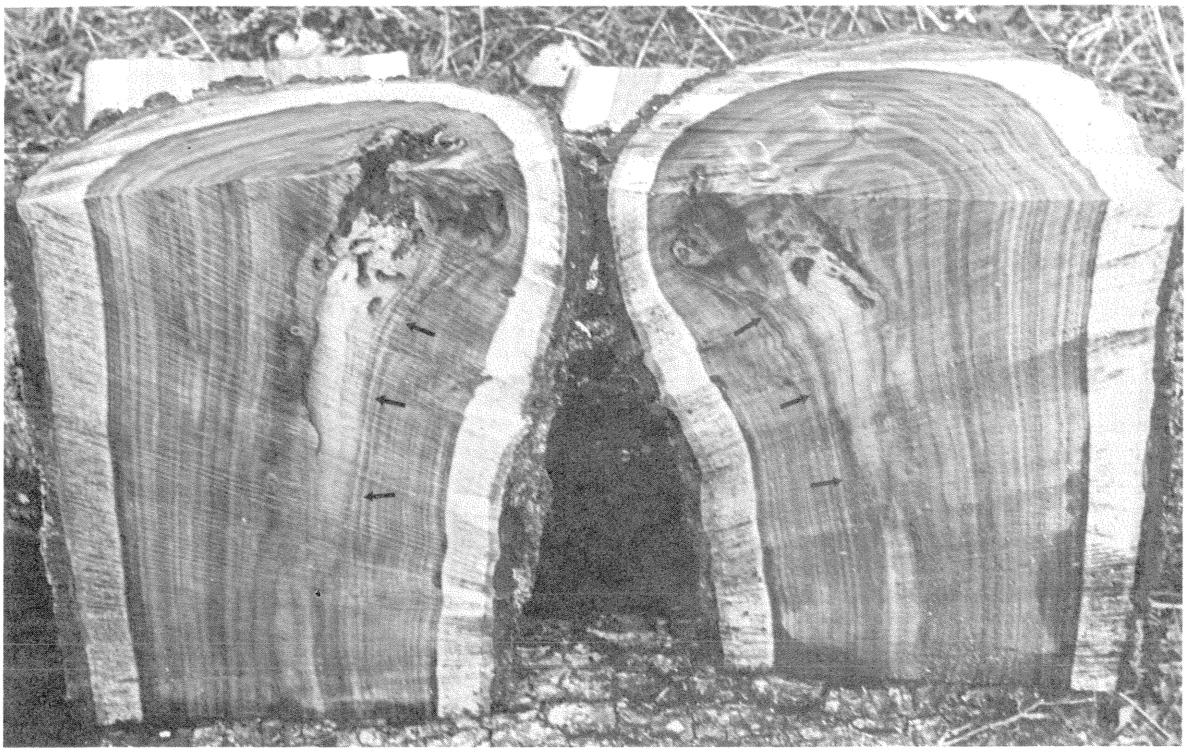


Figure 19.—Internal cracks (arrows) associated with the edges of the wound often move outward, especially during cold weather. Wounds cause the cracks to form, and the cold causes them to move outward.

Figure 20.—Although decay was associated with this stub, and the stub was inhabited by ants, the tissues that formed after the stub died were not infected (arrows). Defects associated with stubs are compartmentalized.



Literature Cited

Clark, F. B. 1955. **Black walnut responds to pruning.** J. For. 53:362-365.

Clark, F. B. 1961. **Climatic injury found on planted black** walnut in Kansas. U. S. Dep. Agric. For. Serv. Cent. States For. Exp. Stn. Note 147. 2 p.

Clark, F. B., and K. W. Seidel. 1961. **Growth and quality of pruned black walnut.** U. S. Dep. Agric. For. Serv. Cent. States For. Exp. Stn. Tech. Pap. 180. 11 p.

Geyer, W. A. 1971. **Reforesting Kansas coal spoils.** Kans. State Univ. Agric. Applied Sci. Circ. 399. 9 p.

Geyer, W. A. 1972. **Timber growth on graded and ungraded strip-mine spoil banks in southeast Kansas.** Trans. Kans. Acad. Sci. 74:318-324.

Geyer, W. A., and G. G. Naughton. 1971. **Growth and management of black walnut** (*Juglans nigra* L.) **on strip-mined lands in southeastern Kansas.** Trans. Kans. Acad. Sci. 73:491-501.

Geyer, W. A., and N. F. Rogers, 1972. **Spoils change and tree growth on coal-mined spoils in Kansas.** J. Soil Water Conserv. 27:114-116.

Maeglin, R. R., and N. D. Nelson. 1970. **Surface soil properties of black walnut sites in relationship to wood color.** Soil Sci. Soc. Am. Proc. 34:142-146.

McGinnes, E. A. 1968. **Extent of shake in black walnut** (*Juglans nigra* L.). For. Prod. J. 18:80-82.

McGinnes, E. A., Jr. 1975. **Response of black walnut to environmental mishaps.** 66th Annu. Rep. North. Nut Grow. Assoc. p. 102-107.

McGinnes, E. A., Jr., C. I-J Chang, and K. Y-T. Wu. 1971. **Ring shake in some hardwood species: The individual tree approach.** J. Polym. Sci.: Part C. 36:153-176.

McGinnes, E. A., Jr., J. E. Phelps, and J. C. Ward. 1974a. **Ultra-structure observations of tangential shake** formations in hardwoods. Wood Sci. 6:206-211.

McGinnes, E. A., Jr., and A. L. Shigo. 1974b. **A note on the effects of wounds on heartwood formation in white oak** (*Quercus alba* L.). Wood Fiber 6:327-331.

McGinnes, E. A., Jr., and A. L. Shigo. 1975. **Electronic technique for detection of discoloration, decay, and injury-associated ring shake in black walnut.** For. Prod. J. 25:30-32.

McGinnes, E. A., Jr., P. J-Y. Lieu, and J. E. Phelps. 1976. **Analysis of wood formation associated with tree injury: Loose heart in a white oak, the radial seams and cracks in two black oaks.** Appl. Polym. Symp. No. 28. p. 1261-1282.

Moslemi, A. A. 1967. **Quantitative color measurement for black walnut wood.** U. S. Dep. Agric. For. Serv. Res. Pap. NC-17. 16 p.

Neely, D. 1970. **Healing of wounds on trees.** J. Am. Soc. Hort. Sci. 95:536-540.

Nelson, N. D., R. R. Maeglin, and H. E. Wahlgren. 1969. **Relationship of black walnut wood color to soil properties and site.** Wood Fiber 1:29-37.

Rogers, N. F. 1951. **Strip-mined lands of the western interior coal province.** Univ. Mo. Res. Bull. 475. 55 p.

Sharon, E. M. 1973. **Some histological features of** *Acer saccharum* **wood formed after wounding.** Can. J. For. Res. 3:83-89.

Shigo, A. L. 1972. **Ring and ray shakes associated with wounds in trees.,** Holzforschung 26:60-62.

Shigo, A. L. 1975. **Biology of decay and wood quality.** p. 15. *In* Biological Transformation of Wood by Microorganisms. Walter Liese, ed. Springer-Verlag, Berlin.

Shigo, A. L. 1976. **Compartmentalization of discolored and decayed wood in trees.** p. 221-226 *In* Material and Organismen Beiheft 3. Verlag Duncker and Humbolt, Berlin.

Shigo, A. L., and E. vH. Larson. 1969. **A photo guide to the patterns of discoloration and decay in living northern hardwood trees.** U. S. Dep. Agric. For. Serv. Res. Pap. NE-127. 100 p.

Shigo, A. L., W. C. Shortle, and P. W. Garrett. 1977a. **Compartmentalization of discolored and decayed wood associated with injection-type wounds in hybrid poplar.** J. Arboric. 3:114-118.

Shigo, A. L., W. C. Shortle, and P. W. Garrett. 1977b. **Genetic control suggested in compartmentalization of discolored wood associated with tree wounds.** For. Sci. 23: 179-182.

Solomon, D. S., and A. L. Shigo. 1976. **Discoloration and decay associated with pruning wounds in yellow birch.** For. Sci. 22:391-392.

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