GENETIC CONTROL OF PRUNING WOUND DEVELOPMENT IN BLACK WALNUT PROGENIES

by

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Abstract.--After pruning, very few wounds had shown any dimensional changes but both dieback and healing were common to most black walnut progenies. The among-family variation in wound response was 1.4 to 4.1 times as great as the within-family variation. Heritability values were higher for the largest wound than smaller wounds, higher for horizontal dieback than for vertical dieback, and are higher for dieback than for healing. Wound healing was correlated to tree vigor but was not correlated with the latitude of the seed source.

Additional keywords: Dieback, vigor, heritability.

Black walnut (*Juglans nigra* L.) is probably the most precious American tree species. Not only are valuable timber products such as finished furniture, gunstocks and interior paneling produced from the tree, but important markets for the nuts also exist. We may consider black walnut as the "king of the forest" for its timber, "queen of the kitchen" for its nutmeat, and the "ace" of abrasives for its grounded nut shell.

Demand for black walnut logs is not limited to the United States alone but has become a world-wide phenomenon. The result is that for high quality walnut timber the annual cut has far exceeded the net growth since the late 1950's; and for all walnut timber, the annual cut has exceeded net growth since the late 1970s. Increasing demand and dwindling domestic supplies of high quality logs have sent prices for black walnut skyward. In fact, the actual average price of delivered prime grade sawlogs increased at about twice the rate of a number of other important hardwood species between 1954 and 1973 (Callahan and Smith 1974). Because of that, more efficient and complete utilization of the walnut resource is needed.

Pruning of lateral branches can improve the quality of black walnut stems in the following ways:

1. correct forked stem
2. develop a straight center bole
3. improve bole form
4. increase height growth

In terms of economics, Callahan and Smith (1974) found that pruning would yield an internal rate of return around 5%. Potenial returns from investments in

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pruning should be greater for black walnut that for any other hardwood species (Clark and Seidel, 1961).

Profitable as it may sound, pruning may cause a number of wood defects. These defects include ring shakes and wood discoloration. More rapid wound healing can reduce the magnitude of such defects by closing the wound quickly and forming more clear knot-free wood on the main stem.

In this paper we report the wounding response in relationship to genetic control and to tree vigor. The wounding response is expressed either as wound closure or dieback. Some of the pruning wounds that formed callus tissue and reduced its dimension are classified as wound closure (Figure 1). Others, however, experienced a dieback of the cambial tissue around the wound and thus enlarged its size (Figure 2). We also make several recommendations concerning purning operations in black walnut trees based on the results of our observations.

Figure 1. Wound healing is due to the closure of callus tissue.

Figure 2. Dieback of the cambial tissue around the wound.

METHODS

A black walnut plantation in Jackson County, Illinois was established in the spring of 1970. Seeds were collected from 80 native trees in Illinois, Missouri, Tennessee, Arkansas, and Kentucky. The half-sib progenies were planted in a complete randomized block design. Each linear plot was made up of five seedlings from a mother tree, with each plot being replicated five times in the plantation. Between two adjacent linear plots a filler tree was planted. Spacing was four feet (within plots) by ten feet (between rows).

The filler trees and the two smallest trees in each plot were removed in 1976 to provide greater growing space for the remaining trees. In the summer of 1978, the eight year-old black walnut trees were pruned by Forest Service Youth Conservation Corps. No strict pruning criteria were given to the crews. The pruning that was performed consisted of corrective pruning to improve stem form, and clear-bold pruning to approximately 507. of the live crown. Hand saws were used for the pruning operation.

Starting in the fall of 1978, the vertical and horizontal dimensions of the largest pruning wound and the wound most opposite to the largest were measured on each tree. A micrometer caliper was used to measure the dimension to the nearest 0.01 inch. The same measurements were made again in 1979 and 1980, and the dimension changes over time were calculated. Three time intervals were used to measure dimension change: 1978 to 1979, 1979 to 1980, and 1978 to 1980.

RESULTS

On the average, there were 8 pruning wounds per tree. The family means ranged from 4 to 13 wounds. Very few wounds had shown no dimensional changes but both dieback and healing were common to most trees. As Table 1 shows, dieback in at least one dimension of one wound was observed in 85 to 86 percent of the trees during the three time periods measured. Similarly, from 88 to 93 percent of the trees showed wound healing in at least one dimension of one wound during the same three time periods. Since plants are not capable of replacing injured tissue, the tree reacts to the injury by forming a chemical protective barrier beneath and around the wound. The parenchyma cells, plus cambial activity, give rise to callus tissue and are responsible for wound closure. On the other hand, a wide variety of microorganisms may be involved in the process of breaking down the protective barrier and thus enlarge the

Table 1.--Population frequency of wound dieback and wound healing in at least one dimension on one wound per tree.

Time Interval	Wound Response	
	Dieback	Healing
1978 to 1979	.86	.88
1979 to 1980	.85	.92
1978 to 1980	.86	.93

wound. This may help to explain why wound closure and dieback were so common. A wound just cannot be left alone. Fortunately, the frequency of wound healing increases with time.

It appears that the compartmentalizing capacity of individual trees is under genetic control (Shigo 1978). In order to investigate the degree of genetic control, analyses of variance were performed and heritabilities were calculated to quantify the influence of the seed source on the rate of wound healing and cambial dieback. The results of those tests showed that there are some significant differences among families regarding wound healing and cambial dieback.

Twenty-four different wound response categories were tested (three time periods by two wounds per tree by two dimensions per wound by two wound responses = twenty-four categories), and ten showed significant family differences. The among-family variation was 1.4 to 4.1 times as great as the within-family variation (Table 2). Since seven of the ten significant categories represent dieback responses, it appears that the microorganisms may attack some families with greater success than others. Conversely, some families of black walnut may have stronger protective barriers than others. Family differences in deposition of callus tissue were indicated twice by vertical healing and once by horizontal healing. Thus, in general, family differences tend to be more in dieback responses than in healing responses.

Heritability is defined as the portion of phenotypic variation which is due to genetics. For example, the family heritability of the first year dieback on the largest wound along the horizontal direction is 0.76. Thus about three quarters of the phenotypic variation among the family mean in that category was accounted for by genetic factors, and only one quarter was due to environment. The top three ranked heritability values in Table 2 are associated with the horizontal dieback on the largest wounds. In general, heritability values for the largest wound are bigger than wounds of other sizes, they are greater for horizontal dieback than for vertical dieback, and they are higher for dieback than for healing. It can be argued that larger wounds require greater defensive effort and that trees with lesser defensive effort genetically would suffer greater dieback. Because of the vertical orientation of the vascular tissue, the advancement and penetration of pathogens would be easier along the vertical direction than the horizontal direction. In other words, the defensive walls on the horizontal top and bottom of the compartment are more difficult for the tree to defend than the walls on the left and right. Genetically inferior trees would be most susceptible to attack on the weakest front.

It has long been believed that tree vigor and wound healing are closely linked such that a more vigorous tree will heal its wounds more quickly than a less vigorous tree (Neely 1970). This concept was tested in the study by correlating wound response measurements with measures of tree vigor like crown size and diameter increment. Weak but significant correlation coefficients which supported the traditional belief were observed (Table 3). The wounds of trees with larger crowns and greater diameter growth tended to heal faster and dieback less than trees with smaller crowns and less diameter growth.

Table 2.--Heritabilities of significant wound response categories.

Category	F-Ratio[a]	Heritability
Largest Wound, Horizontal Dieback, 1978-1979	4.11	.76
Largest Wound, Horizontal Dieback, 1979-1980	2.90	.66
Largest Wound, Horizontal Dieback, 1978-1980	2.59	.61
Largest Wound, Vertical Dieback, 1979-1980	1.59	.37
Largest Wound, Vertical Dieback, 1978-1980	2.19	.54
Largest Wound, Vertical Dieback, 1978-1980	2.30	.57
Opposite Wound, Horizontal Dieback, 1979-1980	1.94	.48
Opposite Wound, Vertical Dieback, 1979-1980	1.79	.44
Opposite Wound, Horizontal Healing, 1978-1979	1.40	.29
Opposite Wound, Vertical Healing, 1978-1979	1.61	.38

[a] All values significant at or below the .05 level.

Although a number of traits have been correlated with the latitude of the seed source in black walnut (Bey 1970, 1973, 1980), this study found no such correlation between seed source latitude and wound response.

RECOMMENDATIONS

We have found in this study that there are significant family differences in response to pruning wound and that the genetic control of those responses is strong. Selection to reduce dieback and selection for rapid healing is possible. However, tree improvement and silviculture are not necessarily mutually exclusive. In fact, they should go hand in hand in forest management. Even with the best genotype, reduction of dieback and promotion of wound closure can be accomplished by proper pruning techniques. The following five recommendations, based on the results of this study and the work of others, can be made to walnut managers planning a pruning operation:

1. So much dieback was observed in this study partly because the trees were pruned during the summer when they were actively growing and the vascular cambium was vulnerable to dessication. Therefore, late winter or early spring pruning is recommended

Table 3.--Significant Pearson correlation coefficients between wound response categories and tree vigor characters.

Category	Crown Length	Maximum Crown Radius	Diameter Increment
Largest Wound, Vertical Healing, 1978-1979	-.34[a]	-.30	-.30
Largest Wound, Horizontal Healing, 1978-1979	-.24	-.22	-.31
Opposite Wound, Horizontal Healing, 1978-1979	NS[b]	-.14	NS
Largest Wound, Horizontal Healing, 1979-1980	-.29	-.31	-.32
Opposite Wound, Vertical Healing, 1979-1980	NS	NS	-.17
Opposite Wound, Horizontal Healing, 1979-1980	NS	-.13	-.22
Largest Wound, Horizontal Healing, 1978-1980	-.23	-.30	-.41
Opposite Wound, Vertical Dieback, 1978-1980	-.16	-.18	-.16
Opposite Wound, Horizontal Healing, 1978-1980	-.13	-.18	-.20

[a] The negative coefficient sign indicates that more tree vigor results in more wound healing (a negative wound dimension change) and less wound dieback (a positive wound dimension change).

b NS = Non-significant at .05 level.

to reduce the amount of cambial dieback around the wound (Mayer-Wegelin 1936, Roth 1948, Neely 1970, Smith 1980).

2. Excessive dieback was also observed in the study because some of the pruning wounds were extremely large to begin with (over three inches in diameter). It is recommended that pruning begin at an early age so that the branches pruned are not too large. Schlesinger and Funk (1977) suggest 2.0 inches as the maximum diameter of a pruned branch in black walnut.

3. Some of the branches in the study were not pruned quite flush with the main stem and, thus, slowed down healing. Flush pruning allows for the wound to heal over more quickly. However, if flush pruning results in an extremely large wound, it may be better to prune a little bit away from the main stem and produce a smaller wound (Herring et al. 1958). Also, if

callus has begun to form around a dead branch stub and the stub needs to be removed, one should not cut through the callus since this will generate more defective wood in the main stem (Shigo et al. 1979). Therefore, it is recommended that branches be pruned flush with the main stem unless flush pruning produces an excessively large wound or cuts through live callus.

4. This study measured greater genetic influences on wound dieback than on wound healing. If selection for wound response is to be practiced, it appears that selection against wound dieback will be more effective than selection for wound healing.

5. Overall, the wounds of more vigorous trees tend to dieback less and heal more. Therefore, maintaining good vigor in walnut is the most basic way to ensure positive wound response.

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