NUT PRODUCTION HANDBOOK FOR EASTERN BLACK WALNUT

Technical Editors
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PREFACE

Interest in the species of Eastern Black Walnut (Juglans nigra L.) for commercial nut production continues to increase. During the past several years interested growers have intensified tree care and evaluated several varieties and selections. It is believed that we have arrived at an economically viable threshold for commercial nut production. While we are operating with a strong level of cautious enthusiasm we believe that we are witnessing the emergence of a new industry.

This is the first attempt to create a publication specifically for the commercial production of Eastern Black Walnut nuts. While some areas remain to be explored it is believed by the nut production focus group that we must challenge ourselves and move aggressively forward with the information that we have. Our plan for this publication is to identify the areas of need for the members and potential members of the industry and identify prospective authors. We will revisit the publication and make necessary refinements at a conference in 1999. Most subjects should be adequately treated by then.

The Eastern Black Walnut nut industry has historically functioned with minimal dependence on artificial pest control. It is our goal to encourage the development of this new, emerging industry, to make the necessary genetic selections and develop cultural practices to have limited dependence on pesticides.

It is important that we develop an enterprise that is sustainable and renewable. It must allow growers, workers, processors and consumers to live in a balanced and harmonious environment. This land-use practice must not only be environmentally sound but economically viable. Our efforts are to encourage the development of a commercial eastern black walnut nut industry that is profitable for the grower, the processor, the supportive infrastructure, and one that provides quality competitively priced products for the consumer.

A portion of the funds to produce and distribute this publication have been provided by a grant from the USDA-Forest Service for which we are very grateful.

Editors,

Jim Jones[1]
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Additional materials will be added to this publication. Each "Handbook" has been issued a serial number to allow us to provide update materials as they become available. Please help to maintain the information by registering your name, address, and phone number with the book number.

Inquires regarding this publication for update materials or additional copies, should be addressed to the Southwest Missouri RC&D, 283 U.S. Highway 60 West, Republic, Missouri 65735. Phone: 417-732-6485.

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PART 1

THE HISTORY OF THE EASTERN BLACK WALNUT SPECIES

Black Walnut In The United States

Thomas L. Schmidt[1]

ABSTRACT: -- The current situation of black walnut (Juglans nigra L.) in the United States related to area, volume, growth, mortality, and removals is presented. As of the most recent inventories, there were more than 15 million acres of timberland with black walnut present, 95 percent of which is privately owned. The majority of the black walnut timberland was classed as sawtimber. Growing-stock and sawtimber volume almost doubled between 1963 and 1989. The long-term future for black walnut appears bright due to favorable growth to removal ratios. Aspects of black walnut nut production in relation to the resource are presented.

GROWER RECOMMENDATIONS

Currently, nut production is a secondary consideration of most timberlands with black walnut (Juglans nigra L.) present. Plantations represent only one percent of the total black walnut resource throughout the Nation. Black walnut plantations specifically designed for nut production represent only a fraction of the total black walnut plantations. While the black walnut resource is growing, there has not been a focus on managing this resource for nut production. Demand for black walnut nuts has consistently met or exceeded supply due to the consistently growing demand and inconsistent availability of the nuts produced.

The supply of black walnut nuts and timber would be enhanced if establishment and management were focused on sites with high potential productivity. With the majority of black walnut timberlands owned by non-industrial private landowners, the future supply is dependent on land management goals that include nut and timber production. Private landowners own land for many purposes, if improving the quantity of both black walnut nuts and wood fiber is of high priority, public agencies could target these landowners for increased management, technical assistance, and cost-share programs.

Tree distribution records of state forestry agencies show that more than 3 million black walnut seedlings have been annually distributed throughout the eastern United States in 1990's (Johnson 1995). In addition, there are many private nurseries that distribute black walnut seedlings. To date, plantations have not made a significant impact on the supply of black walnut nuts or timber. However, if this level of planting continues, if the plantations are adequately managed, and if they are planted on productive sites, plantations have the potential to improve the future supply of black walnut nuts and wood fiber. The number of black walnut trees has consistently increased, growing-stock volume has consistently risen, the number of plantations has increased, and demand for nuts

[1] Research Scientist, North Central Forest Experiment Station, USDA Forest Service, 1992 Folwell Ave., St. Paul, MN 55108. This paper represents a follow-up to the paper "Status of Black Walnut in the United States" (Schmidt and Kinsley 1997) presented at the Fifth Black Walnut Symposium, 1996 in Springfield, Missouri. Data presented in this paper are taken directly from the previous paper.

and fiber has consistently risen. If this growing resource is adequately managed, questions about the long-term supply of black walnut for both nuts and timber will be answered.

INTRODUCTION

Black walnut, one of the most highly valued hardwood species, is found throughout most of the eastern half of the United States (Harlow and Harrar 1969). The species is not dominant in most forests, but rather is generally found as scattered single trees or as small isolated groups within hardwood stands (Fischer 1982). Black walnut has a large geographical range but a narrow range of suitable sites where it can grow at an adequate rate.

Since the late 1800's, the supply of black walnut has been a topic of concern. The concern for black walnut has been centered on high quality, large diameter trees but the supply of black walnut nuts has also received attention. In 1880, a Purdue University professor reported that about 85 percent of the black walnut resource in Indiana had been disposed of (Frye 1982). Foresters concerned about the supply of black walnut have historically urged an increase in the management and planting of black walnut (Quigley and Lindmark 1966, Adams 1981). In an address to the Third Black Walnut Symposium, R. Max Petersen recognized that while, for most hardwoods, growth significantly exceeded demand, the situation was quite the opposite for black walnut (Petersen 1982). He estimated that demand for black walnut had been greater than supply for many years and that the gap between demand and supply was projected to widen at an ever increasing rate. From a nut production perspective, demand has consistently met or exceeded supply.

Inventory results from the 1970's seemed to confirm the concerns expressed by forest industries, foresters, and landowners. For example, in Missouri black walnut growing stock decreased from 100 million cubic feet in 1959 to 97 million cubic feet in 1972, and sawtimber decreased from 238 million board feet to 217 million board feet in the same time period (Spencer and Essex 1976). In Iowa, black walnut growing-stock volume decreased by more than a third from 1954 to 1974, going from about 52 million cubic feet to about 32 million cubic feet (Spencer and Jakes 1980). Similar examples of decreasing black walnut volumes in the 1960's and 1970's could be provided for many other states.

Plantations have been viewed as a means to increase the supply of black walnut. While black walnut plantations have not met the expectations of either the producing landowners or the utilizing industries from a timber production standpoint (Schmidt and Kingsley 1997), they do hold great promise for increasing nut production. In light of the many concerns about black walnut, it is important to understand and evaluate black walnut's current status.

METHODS

Data for this paper are from the USDA Forest Service, Forest Inventory and Analysis' (FIA) Eastwide Data Base (EWDB) which contains the most recent statewide forest inventory for each state (Hansen et al. 1992). Data presented pertain only to timberland, however, more than 95 percent of the forest land in the United States is classified as timberland (Powell et al. 1993). Timberland is forest land capable of producing more than 20 cubic feet per acre per year of industrial wood crops under natural conditions and not withdrawn from timber utilization. There are other classifications of forest land that contain black walnut, including reserved forest land, narrow planted and natural wooded strips, and pasture land with trees that do not meet the timberland definition. Significant amounts of black walnut occur on these non-timberlands and they make important contributions to not only the nut and timber supply of black walnut, but also to other forest related benefits. It has been estimated that the majority of the harvested black walnut nuts come from either open-grown forests, pastures with black walnut present, or plantations. The amount of black walnut on non-timberland has been estimated to range from 5 to 25 percent of that found on timberlands. Until recently, FIA did not install field plots on these other lands and, as a result, data are very limited for forestland classifications other than timberlands.

Black walnut is not a recognized forest type but is included within several forest types. Black walnut is a common associate of five forest cover types and is also found as an occasional associated species in four other forest cover types recognized by the Society of American Foresters (Williams 1990). Area data are generated from FIA tree-level records and are based on the existence of at least one 5 inch d.b.h. (diameter at breast height) or larger black walnut within an established FIA field plot. Area data for each state in the black walnut range are generated by this method for ownership, stand-size class, and site productivity class. For stand-size class determinations, sawtimber sized stands are stands with half or more of the total live tree stocking in trees that are at least 11 inches d.b.h. Growing-stock volume is the net volume in cubic feet of growing-stock trees 5.0 inches d.b.h. and over, from 1 foot above the ground to a minimum 4 inch top diameter outside bark (d.o.b.) or to the point where the central stem breaks into limbs. Sawtimber volume, a subset of growing-stock volume, is the net volume in board feet (International 1/4 inch rule) of the saw-log portion of live sawtimber sized trees from 1 foot above ground to a minimum 9 inches top d.o.b.

Dates of the most recent statewide inventories range from 1981 in Kansas to 1993 in Michigan. To determine the average most recent FIA inventory date for black walnut, the inventory year for each state was multiplied by the percent of the total national growing-stock volume represented by each state. This resulted in an average inventory date of 1989. By comparison, Quigley and Lindmark referenced the 1962 appraisal of the timber resources of the United States. Thus, comparisons over time are based on average inventory dates of 1962 and 1989, a 27-year time span.

To estimate the volume of timber produced from timberland, FIA units conduct direct mail canvasses of the mills that process the timber. There are two sources of black walnut timber products: those from timberland and those from lands not considered timberland such as nonforest area with trees, fence rows, and other lands. Thus, it is conceivable that the total volume of products removed can exceed the total volume of growing stock removed. If the total volume harvested was significantly greater than the growing-stock volume removed, it can be assumed that a significant volume was produced from non-growing stock sources (as is often the case).

RESULTS

Area

The most recent inventories indicate more than 15.4 million acres of timberland with black walnut present (Table 1). Of these acres, 99 percent occurred in natural stands and 1 percent was in plantations. Black walnut plantations generally are small, scattered acreages. While the majority of the black walnut plantations were located in Ohio, Kentucky, and Illinois, several additional states have plantations specifically designed for nut production.

Table 1.--Area of timberland with black walnut by ownership class.

State	Most Recent Inventory	Ownership class						
		Total	National forest	Misc. federal	Other Public	Forest Industry	Private individual	Private corporation
		(Thousand acres)						
Missouri	1989	2,569.7	101.1	76.0	50.9	8.3	2,124.3	209.1
Kentucky	1988	1,971.2	46.1	-	15.5	10.3	1,770.3	129.0
Ohio	1991	1,759.8	26.8	-	46.6	19.0	1,532.3	135.1
West Virginia	1989	1,357.8	4.6	7.2	22.1	54.9	1,103.7	165.3
Tennessee	1989	1,234.6	7.7	36.2	11.5	59.7	1,088.3	31.2
Indiana	1986	1,064.2	12.9	31.4	27.5	1.9	907.6	82.9
Illinois	1985	941.5	20.1	-	15.8	4.0	853.1	48.5
Pennsylvania	1989	708.7	-	5.3	5.8	5.5	636.0	56.1
Virginia	1991	577.5	15.8	13.5	10.8	15.2	461.4	60.8
Iowa	1990	536.0	-	6.1	17.9	-	484.5	27.5
Kansas	1981	472.7	-	15.3	1.0	3.4	427.3	25.7
Arkansas	1988	451.4	52.0	6.3	6.2	9.7	343.8	33.4
18 other states		1,769.7	6.6	38.1	82.2	69.3	1,468.3	105.2
Total all states		15,414.8	293.7	235.4	313.8	261.2	13,200.9	1,109.8

There are 30 states with naturally occurring black walnut, however, the walnut resource is not evenly distributed across the Nation. For example, 50 percent of the total timberland area in the United States with black walnut occurred in only 4 states--Missouri, Kentucky, Ohio, and West Virginia (Fig. 1). Twelve states, mostly in the Central Hardwood Region, accounted for almost 90 percent of the total area of timberland with black walnut present.

Comparing the area of timberland with black walnut present to the total area of timberland, Kansas ranks first with almost 40 percent of its timberland having black walnut present. Other states with high percentages of timberlands with black walnut present include Iowa, Indiana, Illinois, Ohio, Missouri, Kentucky, West Virginia, and Nebraska. In these states, at least 10 percent of the total timberland area contain black walnut. By comparison, Pennsylvania was 8th in total area of timberland with black walnut (709 thousand acres) but this was less than 5 percent of their total timberland area (15.9 million acres).

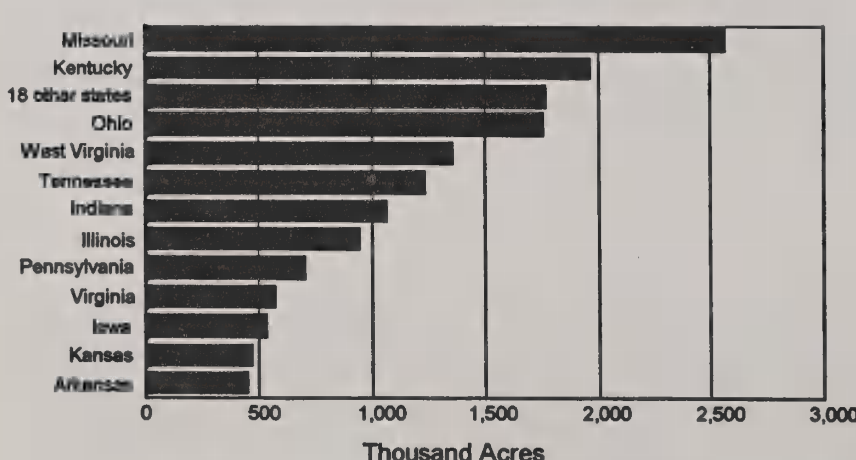

Figure 1. Area of timberland with black walnut present from most recent inventories, by state.

In the most recent inventories, 58 percent of the timberland with black walnut was in sawtimber-sized stands, 28 percent was in poletimber-sized stands, and 14 percent was in sapling-seedling sized stands (Fig. 2). All thirty of the states had the most timberland area with black walnut present in the sawtimber-size class (Table 2). These data represent the average stand size determined from the dominant trees in the stand, black walnut might or might not have been the dominant trees. However, since black walnut seedlings are intolerant of shade and are seldom found under dense tree canopies (Williams 1990), the black walnut size class should be similar to that of the overall stand.

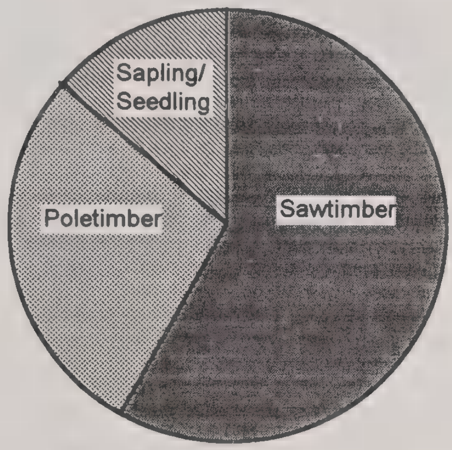

Figure 2. Size class distribution of timberland area with black walnut present.

Table 2.—Area of timberland with black walnut by stand-size class.

State	Total	Stand-size class		
		Sawtimber	Poletimber	Sapling-seedling
	(Thousand acres)			
Missouri	2,569.7	1,293.8	875.4	400.5
Kentucky	1,971.2	1,041.4	648.6	281.2
Ohio	1,759.8	1,012.3	420.1	327.4
West Virginia	1,357.8	774.1	442.8	140.9
Tennessee	1,234.6	659.8	401.3	173.5
Indiana	1,064.2	749.7	176.2	138.3
Illinois	941.5	668.0	173.1	100.4
Pennsylvania	708.7	400.1	236.4	72.2
Virginia	577.5	389.5	143.0	45.0
Iowa	536.0	390.1	107.7	38.2
Kansas	472.7	234.2	113.4	125.1
Arkansas	451.4	196.5	186.6	68.3
18 other states	1,769.7	1,130.9	437.7	201.1
Total all states	15,414.8	8,940.4	4,362.3	2,112.1

Almost 70 percent of the black walnut timberland acreage were located on the two lowest productivity classes (Table 3). Less than 10 percent of the black walnut timberland was classified as being on sites with very high to excellent productivity potential (120 + cubic feet of growth per acre per year). However, there were a few states with significant acreages of black walnut timberland on the higher productivity sites. For example, more than 60 percent of the black walnut timberland in Indiana was located on sites with a potential productivity of at least 85 cubic feet per acre per year. From a nut production perspective, it is critical that plantations be located on the highest productivity sites possible.

Table 3.--Area of timberland with black walnut by site productivity class.

		Productivity class (cubic feet of growth per acre per year)				
State	Total	165+	120 -164	85 -119	50 -84	20 -49
			(Thousand acres)			
Missouri	2,569.7	15.4	28.9	207.9	1,289.0	1,028.5
Kentucky	1,971.2	-	149.9	353.6	605.8	861.9
Ohio	1,759.8	-	58.9	159.9	405.5	1,135.5
West Virginia	1,357.8	-	139.3	404.3	362.6	451.6
Tennessee	1,234.6	52.3	184.0	316.6	485.1	196.6
Indiana	1,064.2	-	206.1	449.6	298.4	110.1
Illinois	941.5	-	47.5	382.8	408.5	102.7
Pennsylvania	708.7	-	65.7	107.9	198.4	336.7
Virginia	577.5	4.6	15.1	158.4	356.3	43.1
Iowa	536.0	3.2	5.8	181.1	260.6	85.3
Kansas	472.7	-	2.1	67.4	220.5	182.7
Arkansas	451.4	4.8	0.0	40.0	280.3	126.3
18 other states	1,769.7	117.2	183.5	539.6	670.4	259.0
Total all states	15,414.8	197.5	1,086.8	3,369.1	5,841.4	4,920.0

Number of Trees

In the most recent inventories, there were almost 500 million black walnut growing-stock trees in the United States (Table 4). More than 90 percent of these trees were located in twelve states. Of the half billion black walnut growing-stock trees, two-thirds were less than 5 inches d.b.h. In the most recent inventories, only 8 percent of the total number of black walnut growing-stock trees were larger than 11 inches d.b.h., considered the minimum size necessary for being classified as sawtimber. Only one percent (5.4 million) of all of the black walnut growing-stock trees in the United States were larger than 17 inches d.b.h.

Table 4.—Number of black walnut growing-stock trees by diameter class.

State	Total	Diameter class (inches d.b.h.)					
		1.0 -4.9	5.0 - 8.9	9.0 - 12.9	13.0 - 16.9	17.0 - 20.9	21.0 +
	(Thousand trees)						
Kentucky	94,453	70,875	14,854	6,507	1,732	410	75
Ohio	76,552	58,244	9,770	5,386	2,408	669	76
West Virginia	63,123	50,553	7,020	3,541	1,544	394	71
Pennsylvania	57,385	46,210	7,051	2,528	1,221	297	77
Missouri	50,936	33,580	9,860	5,417	1,668	376	36
Illinois	26,397	14,548	7,339	2,904	1,240	270	97
Indiana	22,715	11,900	5,686	3,208	1,489	375	56
Kansas	20,969	13,163	4,430	2,406	756	173	41
Iowa	13,677	8,238	2,351	1,920	867	272	29
Virginia	11,413	3,254	3,501	3,000	1,233	335	90
Tennessee	10,732	1,669	4,532	3,242	1,065	194	30
Michigan	7,968	3,470	2,494	1,343	468	160	34
18 other states	43,306	22,064	11,769	6,670	2,083	566	154
Total all states	499,625	337,768	90,657	48,071	17,773	4,491	865

In addition to the half billion black walnut growing-stock trees, there were 91 million non growing-stock black walnut trees (typically rough or rotten trees classified as cull) on timberland in the most recent inventories. Estimates of the number of black walnut trees on non-timberland run as high as an additional 125 million trees. These trees represent an important source of nuts. Black walnut trees in these more "open-grown" conditions tend to have a higher nut production level when compared to trees growing in the more heavily stocked timberland situations. Kentucky, with almost 95 million trees, had the greatest number of black walnut growing-stock trees, almost 20 percent of the total number of black walnut growing-stock trees in the Nation. Ohio, West Virginia, Missouri, and Pennsylvania all had more than 50 million black walnut growing-stock trees.

The number of black walnut trees has been increasing. In Missouri, the number of black walnut trees increased from about 21 million in 1972 to more than 50 million in 1989. In Iowa, the number of black walnut trees doubled from 1974 to 1990, increasing from 7 million to almost 14 million. Similar increases occurred in most of the other states. Although increases occurred in all diameter classes, the majority of the increase in number of black walnut trees was in the smaller diameter classes.

Volume

In 1962, there were more than 1 billion cubic feet of black walnut growing-stock volume on timberland in the United States, 41 percent of which was sawtimber volume (Quigley and Lindmark 1966). In the most recent inventories, there were almost 1.6 billion cubic feet of black walnut growing-stock volume, 41 percent of which was sawtimber (Table 5). This was a 60 percent increase in total volume from 1962 to 1989, representing an average increase of about 22 million cubic feet per year. Interestingly, the ratio of sawtimber volume to growing-stock volume remained about the same between the two time periods.

In addition to the black walnut volume found on timberlands, there are large quantities growing in pastures, narrow wooded strips, and other areas not classified as timberland. As previously mentioned, these areas are not included in the volume estimates but they do contribute to the overall supply of black walnut nuts and wood fiber in the United States.

Table 5.--Volume of black walnut growing stock by diameter class.

State	Total	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21+
		Diameter class (inches d.b.h.)								
		(Million cubic feet)								
Ohio	183.6	13.5	21.2	29.1	36.0	36.4	18.0	15.4	10.0	4.2
Kentucky	183.3	19.6	33.2	42.7	27.4	22.8	17.5	11.7	3.6	5.0
Missouri	147.5	11.9	22.4	29.6	26.6	24.5	14.4	11.1	4.8	2.3
Indiana	127.2	7.4	17.1	19.0	23.0	19.8	21.3	10.2	5.9	3.5
West Virginia	123.7	9.7	16.7	22.4	19.9	23.2	13.5	9.8	4.5	4.0
Illinois	119.1	11.5	18.5	16.7	22.7	20.7	11.7	7.9	3.7	5.7
Virginia	115.2	4.1	10.0	21.1	18.3	23.2	11.4	6.3	12.5	8.3
Pennsylvania	100.5	9.5	16.5	13.9	16.1	17.3	10.6	7.2	4.7	4.8
Tennessee	91.3	6.2	11.4	19.3	17.8	14.9	11.3	4.2	3.8	2.3
Iowa	63.8	2.9	4.6	9.4	12.0	13.0	7.7	6.2	5.9	2.2
Kansas	58.4	7.9	6.0	9.6	11.0	8.0	5.9	4.6	2.0	3.4
Michigan	54.4	4.4	6.4	9.4	9.5	8.4	5.7	5	2.9	2.9
18 other states	220.1	14.6	31.3	42.4	40.3	29.3	28.3	14.5	9.6	9.7
Total all states	1,588.1	123.2	215.3	284.6	280.6	261.4	177.2	114.0	73.7	58.1

Only 8 percent of the total growing-stock volume in the United States was in diameter classes larger than 19 inches d.b.h. The majority of the growing-stock volume was in diameter classes from 9 to 15 inches d.b.h., reflecting a resource that has the potential to greatly expand its volume, assuming these medium sized trees continue to mature (Fig. 3). If market pressures increase to where smaller sized sawtimber trees are harvested, the potential for greatly increasing the volume will be diminished.

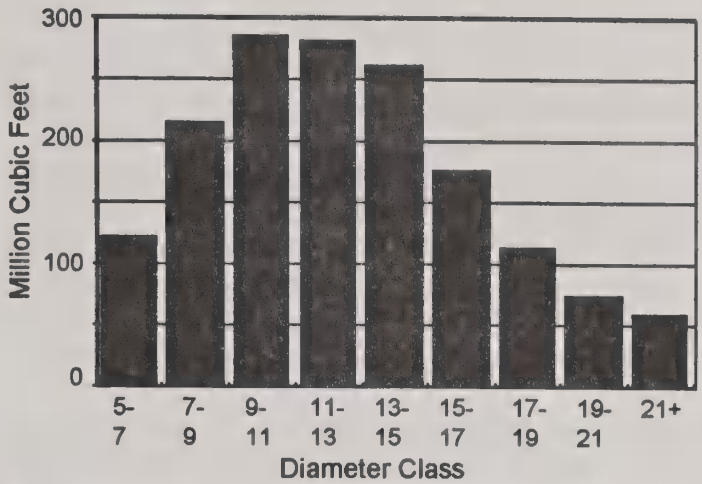

Figure 3. Black walnut growing-stock volume by diameter class.

Ohio and Kentucky had the most black walnut growing-stock volume, each with about 183 million cubic feet (Table 5). These two states accounted for almost one-fourth of the total black walnut growing-stock volume in the United States. While these two states had similar totals, they differed in diameter class distribution. Ohio tended to have more volume in trees 11 inches d.b.h. and greater while Kentucky had more volume in trees less than 11 inches d.b.h.

In 1962, there were an estimated 2.7 billion board feet of black walnut sawtimber (Quigley and Lindmark 1966). As of 1989, there were 4.3 billion board feet of black walnut sawtimber (Table 6). Over the 27-year period between the two estimates, black walnut sawtimber volume increased by almost 70 percent, averaging an increase of about 59 million board feet per year.

Table 6.—Volume of black walnut sawtimber by diameter class.

		Diameter class (inches d.b.h.)					
State	Total	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21+
		(Thousand board feet [1])					
Ohio	510,820	143,700	155,297	82,845	65,743	43,858	19,377
Indiana	427,500	113,062	101,737	111,392	53,600	30,390	17,320
Missouri	398,063	127,338	117,467	68,453	52,050	22,325	10,430
Illinois	368,033	111,592	106,211	61,051	41,740	19,171	28,269
Kentucky	363,548	98,539	90,715	76,189	54,308	18,874	24,924
West Virginia	306,088	71,492	92,027	58,740	40,756	21,305	21,769
Virginia	301,859	62,459	84,257	43,205	25,101	51,009	35,828
Pennsylvania	251,310	59,690	71,349	45,508	31,511	21,880	21,372
Tennessee	244,059	69,949	69,431	54,150	21,012	19,161	10,357
Iowa	223,198	57,822	62,394	36,931	29,077	27,230	9,745
Kansas	170,256	52,427	40,291	30,144	23,267	9,463	14,665
Michigan	160,997	41,073	39,127	27,372	24,518	14,321	14,586
18 other states	570,843	158,613	126,882	120,821	69,986	48,505	46,035
Total all states	4,296,573	1,167,755	1,157,184	816,799	532,668	347,492	274,675

[1] International 1/4 inch rule.

In addition to the sawtimber volume, there are many black walnut trees that are considered "short-log" trees and are not included in the sawtimber volume estimates. To be included in sawtimber volume estimates, a minimum of one 12-foot, or two non-contiguous 8-foot, sawlogs is required. In western portions of the black walnut range, trees often do not reach sufficient height to contain the minimum sawlog requirement. However, industry will use smaller length logs if they meet other quality and size standards. For example, in Nebraska short-log black walnut trees represent an additional 7 percent of the total black walnut sawtimber volume in the state. Many of these trees are of the highest quality and are marketed worldwide. In addition, log-length does not impact the potential nut production capability.

Considering only large trees (>21 inches d.b.h.), Virginia had the most volume followed by Illinois, Kentucky, West Virginia, and Pennsylvania. All five of these states had at least 20 million board feet of sawtimber in the largest diameter class. In Virginia, 29 percent of the total black walnut sawtimber volume in the state was in trees at least 19 inches d.b.h., compared to a national average of 14 percent. Virginia alone accounts for 14 percent of the black walnut sawtimber volume larger than 19 inches d.b.h. in the Nation. As one compares the sawtimber volumes for smaller diameter classes, other states begin to dominate but Virginia is the current king of large diameter black walnut sawtimber.

Growth, Mortality, and Removals

Black walnut growing stock averaged 55 million cubic feet of gross growth and about 11 million cubic feet of mortality each year across the country in the most recent inventories (Table 7). The result was an average annual net growth rate of 44 million cubic feet, 2.7 percent of the Nation's total growing-stock volume. This annual net growth would provide enough wood to make almost a million desks completely out of black walnut or make a stack of black walnut wood four feet high and four feet wide that would stretch from Springfield, Missouri to Richmond, Virginia.

States with above average annual net growth rates when compared to total growing-stock volume include Kansas, Pennsylvania, Illinois, Iowa, Michigan, and Indiana. Kansas and Pennsylvania led all states, each averaging annual net growth rates that were 3.7 percent of their total growing-stock volume. Missouri and Virginia show the lowest percent of growing-stock growth to total volume ratio in the United States, both having a net growth rate of less than 2 percent. Missouri's lower net growth rate was in-part due to higher than average mortality rates.

Average annual mortality was estimated to be 0.7 percent of the Nation's total black walnut growing-stock volume. Of the known causes of black walnut mortality as identified by FIA field crews, weather related factors and diseases were most commonly reported. Tennessee and Missouri had the highest average annual mortality rates, both being about 1.2 percent of total volume. States with low mortality rates included Iowa, Michigan, Pennsylvania, West Virginia, and Kansas. Iowa's black walnut average annual mortality rate was a mere 0.2 percent of its total growing-stock volume.

Table 7.--Black walnut growing-stock volume and average annual growth, mortality, and removals.

	Growing stock					
State	Volume	gross growth	Mortality	net growth	removals	net gain /loss
	(Thousand cubic feet)					
Ohio	183,618	5,751	1,049	4,702	2,635	2,067
Kentucky	183,349	5,521	1,454	4,067	2,279	1,788
Missouri	147,480	4,120	1,789	2,331	2,103	228
Indiana	127,223	5,309	1,335	3,974	1,978	1,996
West Virginia	123,743	4,063	604	3,459	1,086	2,373
Illinois	119,080	5,335	1,186	4,149	875	3,274
Virginia	115,219	2,723	636	2,087	2,746	-659
Pennsylvania	100,498	4,068	359	3,709	449	3,260
Tennessee	91,251	3,556	1,312	2,244	865	1,379
Iowa	63,757	2,372	159	2,213	699	1,514
Kansas	58,370	2,480	305	2,175	485	1,690
Michigan	54,447	1,939	181	1,758	474	1,284
18 other states	220,107	8,895	1,070	7,825	2,699	5,126
Total	1,588,142	55,182	11,534	43,648	19,373	24,275

Growing-stock average annual removals averaged 19 million cubic feet per year, about 1.2 percent of the total volume. Most states had statistically similar growing-stock removal rates, although Virginia reported a removal rate (2.4 percent of its total growing-stock volume) that was double the national average. Even though Virginia has only 63 percent of the growing-stock volume of Ohio, it has a higher removal rate. The high removal rates in Virginia probably could be attributed to harvesting and urban/suburban sprawl pressures. In the long-term, this high removal rate will impact the potential nut production.

If mortality and removals are subtracted from total gross growth, the net result is an increase of 24 million cubic feet of black walnut wood each year in the United States. This compares to the average annual increase of 22 million cubic feet of black walnut that was calculated based on comparing 1962 total growing stock with 1989 total growing stock (see discussion in volume section). Thus, the average annual increase in growing stock is probably between 22 and 24 million cubic feet. Comparing average net growing-stock growth to removals shows a ratio of 2.25/1.0, reflecting a growing resource with long-term sustainability.

The national average net annual gain in volume of black walnut of between 22 and 24 million cubic feet represents about 1.5 percent of the Nation's total black walnut growing-stock volume. The net annual increase in growing-stock volume as a percentage of the state's total growing-stock volume was largest in Pennsylvania, Kansas, and Illinois. Each of these states have a net annual increase of at least 2.5 percent of their total growing-stock volume. Missouri, with a net annual gain of 228 thousand cubic feet or 0.1 percent, is nearly static in terms of annual changes in total growing-stock volume. This is primarily due to above average mortality and removal rates. The current condition in Virginia is different than in any other state in the entire range of black walnut, primarily due to its large volume of sawtimber-sized trees. Virginia is experiencing an annual decrease of 659 thousand cubic feet. If current conditions continue in Virginia, the black walnut resource will dwindle, which will have adverse impacts on both the potential nut production and forest industry.

Sawtimber Quality

Black walnut sawtimber removals have a direct relationship to the quality of the trees available. Therefore, discussions concerning resource quality must precede discussions of the utilization of the resource. In 1965, approximately 45 percent of the volume in walnut sawtimber in Illinois, Kentucky, and Missouri was in grades 1 and 2 (Quigley and Lindmark 1965). As a comparison, 38 percent of the black walnut sawtimber in the most recent inventories were grade 1 or 2 (Table 8).

Many field foresters, log-buyers, and industry officials feel that the decrease in quality was partially the result of a decrease in the size of the timber available for harvest. However, a comparison of sawtimber volume by diameter classes between 1962 and 1989 show that, in fact, the average diameter of sawtimber trees in the United States has been increasing. The percent of black walnut sawtimber in the largest diameter classes, above 19 inches d.b.h., actually increased from 10 percent in 1962 to 14 percent in 1989.

Table 8.—Percent of black walnut sawtimber by grade.

State	Grade 1	2	3	4
	(Percent)			
Ohio	9	22	63	7
Indiana	11	30	50	9
Missouri	5	19	45	31
Illinois	13	38	41	8
Kentucky	12	34	50	4
West Virginia	13	31	38	18
Virginia	4	30	55	11
Pennsylvania	3	25	46	26
Tennessee	5	18	63	14
Iowa	12	34	50	4
Kansas	24	37	39	0
Michigan	20	46	31	3
18 other states	10	27	53	10
Total	10	28	51	11

More than half of the black walnut sawtimber in the United States was graded as grade 3 in the most recent inventories. This grade is suitable for lumber and other miscellaneous products and can often have more "character" than higher grades. For example, furniture made from low grade black walnut lumber with knots and other sound defects adds to the charm and diversity of each piece (Chenoweth 1995).

From a nut production perspective, tree grade is not of major importance. In fact, the best nut producing trees are often those with lower grades because they have more limbs to produce nuts. Black walnut products come from a wide variety of sources beyond the typical forestlands. Because of the economic value associated with black walnut, the eastern United States are scoured for trees that are of the size and condition for producing nut and for the timber industry. Aside from black walnut, there are not many tree species where cull and nonforest trees are considered of economic value.

Current Annual Removals

Current annual removals are estimated for wood fiber products only, current annual nut production can be more accurately estimated by others. In the North Central Region, an estimated 7 million cubic feet of black walnut growing-stock and 5.3 million cubic feet of black walnut non-growing stock are currently harvested based on the most recent Timber Product Output surveys (Table 9). Of the harvested black walnut, about 82 percent (10.1 million cubic feet) was removed from the site, generally to a processing facility and 18 percent (2.2 million cubic feet) was left on the ground as logging residue/slash.

Missouri and Indiana were the leading states in the North Central Region in current annual total black walnut harvested volume. These two states had similar levels of growing-stock removals but different levels of non-growing stock removals. Missouri, in 1993, had more black walnut harvested from non-growing stock sources (2.5 million cubic feet) than from growing-stock (1.8 million cubic feet). Indiana's 1990 black walnut harvest from growing stock (1.8 million cubic feet) was five times the harvesting from non-growing stock (343 thousand cubic feet). States besides Missouri in the North Central Region with a large percentage of total black walnut harvest from non-growing stock include Iowa and Wisconsin.

Almost 20 percent of all of the black walnut harvest in the North Central Region was from cull (non-growing stock) trees. Cull trees are on timberlands but they do not meet the requirements for growing stock. Cull trees include short-log trees, trees with excessive sweep and/or crook, trees with excessive taper to where they do not meet the minimum top diameter, and rotten trees. While FIA classifies these as cull trees, they obviously constitute an important part of the supply of black walnut in the region. Missouri and Iowa both had significant volumes of cull black walnut trees that were harvested for sawlogs. In addition to the cull tree harvest, more than 1.3 million cubic feet of black walnut are harvested annually in the North Central Region from trees that are not on timberlands. These trees occur on pasture land, in narrow wooded strips, in windbreaks, and in other locations and generally provide a significant portion of the annual nut harvest.

Table 9. Black walnut growing stock and non-growing stock annual harvest by state and product in the North Central region.

State and product	Growing stock			Non-growing stock						Total		
	Poletimber/ Sawtimber	Logging residue	Total	Limbwood	Cull trees	Dead trees	Nonforest trees	Logging slash	Total	Used	Not used	Harvested
	(Thousand cubic feet)			(Thousand cubic feet)						(Thousand cubic feet)		
Iowa (1988)												
Sawlogs	463.6	68.9	532.6	-	478.4	-	175.6	225.7	879.8	1,117.7	294.6	1,412.3
Veneer logs	154.4	12.1	166.4	-	0.0	-	22.6	1.1	23.7	177.0	13.2	190.2
Iowa Total	618.0	81.0	699.0	-	478.4	-	198.3	226.8	903.5	1,294.7	307.8	1,602.5
Illinois (1983)												
Sawlogs	674.3	64.4	738.7	14.8	21.6	-	97.1	95.0	228.5	807.8	159.3	967.1
Veneer logs	126.1	9.8	135.9	-	-	-	18.5	9.5	28.0	144.5	19.4	163.9
Illinois Total	800.4	74.2	874.6	14.8	21.6	-	115.5	104.5	256.5	952.3	178.7	1,131.1
Indiana (1990)												
Sawlogs	1,503.0	143.5	1,646.5	32.9	48.2	-	216.4	211.7	509.2	1,800.5	355.2	2,155.7
Veneer logs	307.2	24.0	331.2	-	-	-	45.0	23.2	68.2	352.2	47.2	399.5
Indiana Total	1,810.2	167.5	1,977.7	32.9	48.2	-	261.4	234.9	577.5	2,152.7	402.4	2,555.1
Kansas (1993)												
Sawlogs	370.3	35.3	405.6	8.1	11.9	-	53.3	2.3	75.6	443.6	37.7	481.3
Veneer logs	74.0	5.8	79.8	-	-	-	10.8	0.5	11.4	84.8	6.3	91.2
Kansas Total	444.3	41.1	485.4	8.1	11.9	-	64.2	2.9	87.0	528.4	44.0	572.4
Michigan (1992)												
Sawlogs	372.4	45.5	417.8	8.0	6.4	-	-	68.9	83.4	386.8	114.4	501.2
Veneer logs	47.4	8.9	56.3	0.1	5.1	-	-	13.4	18.7	52.7	22.3	75.0
Michigan Total	419.8	54.3	474.1	8.1	11.6	-	-	82.3	102.1	439.5	136.7	576.2
Minnesota (1992)												
Sawlogs	35.8	8.5	44.3	0.2	1.1	-	-	16.4	17.8	37.2	24.9	62.1
Veneer logs	37.3	7.0	44.3	0.1	4.0	-	-	10.6	14.7	41.4	17.5	59.0
Minnesota Total	73.1	15.4	88.6	0.3	5.2	-	-	27.0	32.5	78.7	42.4	121.1
Missouri (1991)												
Charcoal	8.4	-	8.4	1.4	14.7	0.1	1.7	-	18.0	26.3	-	26.4
Misc. products	33.0	3.0	36.0	-	0.0	-	-	-	-	33.0	3.0	36.0
Sawlogs	1,451.8	215.8	1,667.6	-	1,498.1	-	550.0	706.7	2,754.8	3,499.9	922.5	4,422.5
Veneer logs	338.4	52.3	390.7	-	316.1	-	111.6	3.2	430.9	766.2	55.5	821.6
Missouri Total	1,831.5	271.1	2,102.7	1.4	1,828.9	0.1	663.3	709.9	3,203.8	4,325.4	981.0	5,306.4
Nebraska (1993)												
Sawlogs	71.9	6.9	78.8	1.6	2.3	-	10.4	0.5	14.7	86.2	7.3	93.5
Veneer logs	9.0	0.7	9.7	-	-	-	1.3	0.1	1.4	10.3	0.8	11.1
Nebraska Total	80.9	7.6	88.5	1.6	2.3	-	11.7	0.5	16.1	96.5	8.1	104.6
Wisconsin (1994)												
Sawlogs	189.0	25.9	215.0	1.6	5.3	24.3	-	98.5	129.7	220.3	124.4	344.6
Veneer logs	36.0	6.7	42.7	0.1	3.9	-	-	10.2	14.2	40.0	16.9	56.9
Wisconsin Total	225.0	32.6	257.7	1.7	9.2	24.3	-	108.7	143.9	260.2	141.3	401.5
Total	6,265.4	744.9	7,048.3	68.9	2,417.4	24.4	1,314.3	1,497.6	5,322.7	10,128.5	2,242.5	12,371.0

CONCLUSIONS

Several state inventory results from the 1940's through the 1970's seemed to confirm the concerns expressed about the perceived dwindling supply of black walnut. Other states, however, were showing significant gains in volume. Ohio, the number one black walnut State in terms of growing-stock volume, posted a 22 percent increase in growing-stock volume from 1968 to 1979. Kentucky dramatically increased its black walnut growing-stock volume from 1963 to 1975. Thus, the changing black walnut picture was different depending where one looked. Overall, national compilations show a significant increase in black walnut volume. Inventories in the 1980's and early 1990's show significant gains in black walnut growing-stock volume in all of the primary walnut states. Illinois and Indiana showed the most impressive gain, rising from 44.9 million cubic feet in 1962 to 119.1 million by 1985 and from 64.5 million cubic feet in 1967 to 127.2 million in 1986, respectively.

Why this sudden increase? During this same period, the volume of all hardwoods increased dramatically as hardwood forests matured. However, the rate of increase of black walnut was significantly greater than for other hardwoods. This perhaps may be explained by two factors. First, because black walnut is pest resistant and alleopathic, growth is seldom impeded. Secondly, many black walnut trees were already well established in pasture land that reverted to forest land in the 1970's and 1980's. These trees, with their significant volumes, would have been new additions to the total growing-stock volume.

More than half of the existing black walnut timberlands are in sawtimber-sized stands. These stands have limited potential for redirecting management toward improved quality and stocking rate. Additionally, many of these older stands have been subjected to practices such as grazing that limit their long-term productivity. Returns on investments are limited in older stands when compared to similar investments on younger stands. However, more than two-thirds of the black walnut trees in the United States are currently less than 5 inches d.b.h., which is an excellent size to actively manage for both nut and timber production. In this size class, pruning, releasing, thinning, and other management activities have the potential to greatly improve the quality as well as the quantity of black walnut in the stand, especially if they are on highly productive sites.

The supply of black walnut nuts and timber would be enhanced if establishment and management were focused on sites with high productivity potential. With the majority of black walnut timberlands owned by non-industrial private landowners, the future supply is dependent on land management goals that include nut and timber production. Private landowners own land for many purposes, if improving the quantity of black walnut is of high priority, public agencies could target these landowners for increased management, technical assistance, and cost-share programs. To date, plantations have not made a significant impact on the supply of black walnut. However, if the current level of planting continues, if they are adequately managed, and if they are planted on productive sites, plantations have the potential to improve the future supply of black walnut.

The overall future for black walnut appears bright, the number of black walnut trees has been consistently increasing, growing-stock volume has consistently been on the rise, and the number of plantations has been constantly increasing. If this growing resource is adequately managed, questions about the long-term supply of high quality of black walnut for both nuts and timber will be answered.

APPENDIX

Literature Cited

Adams, D.M. 1981. Black walnut trees make wasteland profitable. Farm, Ranch, and Home Quarterly, Institute of Agriculture and Natural Resources, Univ. Nebraska, Lincoln. Vol. 27: (4): 14-15.

Chenoweth, R.T. 1995. Black walnut. Sagamore Publishing Inc., Champaign, IL. 334 p.

Fischer, B.C. 1982. Principles of managing black walnut in natural stands. P. 92-95. In: Black Walnut for the Future. Gen. Tech. Rep. NC-74. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 151 p.

Frye, L.R. 1982. Walnut resource: availability and utilization. P. 142-144. In: Black Walnut for the Future. Gen. Tech. Rep. NC-74. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 151 p.

Hansen, M.H.; Frieswyk, T.; Glover, J.F.; Kelly, J.F. 1992. The eastwide forest inventory data base: users manual. Gen. Tech. Rep. NC-151. St. Paul, MN: U. S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 48 p.

Harlow, W.M.; Harrar, E.S. 1969. Textbook of dendrology. Fifth edition. McGraw-Hill, Inc. New York, NY. 512 p.

Johnson, J.E., 1994 black walnut seedling production. Walnut Council Bulletin Vol. 22: (2): 13.

Petersen, R.M. 1982. Walnut in perspective: the challenge continues. P. 4-6. In: Black Walnut for the Future. Gen. Tech. Rep. NC-74. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 151 p.

Powell, D.S.; Faulkner, J.L.; Darr, D.R.; Zhu, Z.; MacCleery, D.W. 1993. Forest resources of the United States, 1992. Gen. Tech. Rep. RM-234. Ft. Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 132 p.

Quigley, K.L.; Lindmark, R.D. 1966. Timber resources. P. 6-12. In: Black walnut culture. Walnut symposium. Carbondale, IL., August 2-3, 1966. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 94 p.

Schmidt, T.L.; Kingsley, N.P. 1997. Status of black walnut in the United States. P. 9-22. In: Knowledge for the future of black walnut: Proceedings of the Fifth Black Walnut Symposium. Springfield, MO., July 28-31, 1996. Gen. Tech. Rep. NC-191. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 135 p.

Spencer, J.S., Jr.; Essex, B.L. 1976. Timber in Missouri, 1972. Resour. Bull. NC-30. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 108 p.

Spencer, J.S., Jr.; Jakes, P.J. 1980. Iowa forest resources, 1974. Resour. Bull. NC-52. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 90 p.

Williams, R.D.. 1990. Juglans nigra L. - Black walnut. P. 391-399. In: Silvics of North America: 2. Hardwoods. 1990. Burns, R.M. and Honkala, B.H. tech. coords. Ag. Handbook 654. vol. 2. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 877 p.

History of the Eastern Black Walnut Nut Industry

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Most writings, papers and books on the subject of the Eastern Black Walnut have been almost one hundred percent directed to the growing of Eastern Black Walnut trees and treating the nut merely as a seed which may, with proper care, ultimately become a tree. Few papers and certainly no book has been published on the subject of shelling and processing Black Walnut nuts for human consumption. To my knowledge, no paper has ever been written which would give proper credit to those persons and companies that have been "the industry" in the 20th century. Therefore, I am pleased to accept the challenge for hopefully presenting at least some of the facts about how the industry developed and by whom.

Most of my knowledge comes from my own experiences in running the business which was started by my father, B. Ralph Hammons, in the year 1946. In 1946, I understood that his was sort of the beginning of the industry and I guess that really was the beginning , but I later learned that even prior to 1946 in many parts of the United States where Black Walnut trees are native and where the nuts grow wild, various individuals, had tried to find a way to crack and process the nuts commercially. One of the first in the business and possibly where it all started was Mr. E. A. Smalley, who, while living in Kansas City, Missouri, invented a way to separate small particles of soft nut meats from the hard shells by machine. Mr. Smalley first patented the process, moved to Knoxville, Tennessee and then founded Smalley Manufacturing Company to build its machines. His machine was mostly sold and used in the pecan industry at first, but he adapted his machine for sorting Black Walnut nutmeats as well. Mr. Smalley also built and installed the first machines used to crack the hard-shelled Black Walnuts and most all efficient high volume cracking machines built since that time have at least some of the same principles as discovered by Mr. Smalley.

Several small companies were started in the mid 1940's and one of the first was in Sulphur Springs, Arkansas. It was started with a group of employees using hammers to crack the nuts and others picking out the goodies and sorting and separating the good nutmeats from the shell - - all by hand. That company moved to Gravette, Arkansas in 1955 and was re-organized as Gravette Shelling Company, owned and managed by Mr. Mandel Raffee. When Mr. Raffee died in 1965, the company was purchased by the Hammons Products Company and managed by Mr. Lloyd P. Harris of Gravette. Another company was the Akar Walnut Company. Mr. Akar cracked Black Walnuts in a plant in Morristown, Tennessee and then transported the nutmeat goodies to his plant in Broadway, Virginia for final processing, inspection and boxing. Mr. Akar developed health problems and closed his operations around 1960. Another plant in Virginia was located in the town of Staunton in the Shenandoah Valley, but that plant closed in 1946.

Two other plants were started in Nashville, Tennessee, sometime in the mid 1940's. One was called Block Brothers which was owned and operated by Mr. George Block and his brother, Sam Block. George's son-in-law, Jimmy Cox, ran the company from about 1950 until his death around 1980 and the business was closed at the time. The Block company was mainly in the business of buying and selling furs, hides, roots and herbs. The other plant in Nashville was located directly across the street from Block Brothers near downtown Nashville. It was owned and operated by Mr. Frank

Fleishman and Mr. Fleishman sold his business to the Block company around 1970. The Mick Walnut Company was started along about that time also with a small plant in Kentucky. Mr. Mick operated the plant in the late 50's and early 60's but then closed after a few years. Some other start-up plants were in existence in Kentucky in the mid 40's and 50's but none lasted more than a few short years. The R.E. Funsten Nut Company, located in St. Louis, Missouri owned a shelling plant in Kentucky in the 50's. They shelled and processed black walnuts but they closed their plant around 1960. Barnes Walnut Company was started in Bolivar, Missouri in the early 1950's by Mr. Bufford Barnes. Mr. Barnes sold his business to the Funstein Company around 1975 but then the Funstein Company closed in 1980. Indiana Walnut Company was started in 1987 by Mr. Norman O. O'Bryan in Lafayette, Indiana but the business lacked financing and only lasted about three years.

While the efforts of these many companies greatly added to the demand and marketability for Eastern Black Walnut nutmeats while companies were in business, the Hammons Products Company located in Stockton, Missouri has played a major role in developing the industry as we know it today. My father, B. Ralph Hammons owned a retail grocery, feed and produce business in the small rural town of Stockton. In 1945, there was a large crop of Black Walnuts in Missouri, there was no market for the crop, and the crop of nuts was just going to waste. Dad learned that the plant in Staunton, Virginia was needing more nuts and he contracted with them to buy and sell the nuts he could get here in Missouri. So he organized a buying program with produce dealers and companies in many of the small towns in southwest Missouri and he brought some three million pounds of nuts that were hand-hulled, sun-dried and packed in burlap bags. He hauled the nuts by truck to a rail siding in the town of Diggins, Missouri, east of Springfield, and shipped them to the plant in Virginia. The plant in Virginia closed down the next year so Dad decided to take a chance and put in his own plant in Stockton. That first year, 1946, he bought only one hundred thousand pounds of nuts but at least that was a beginning. Of course, the business grew through the dedication and determination of my father and others working with him. The company now averages buying and processing approximately 26 million pounds of nuts in shell each year that are purchased from buying stations located across sixteen states.

The main reason that Hammons Products Company has survived and grown where others did not was keen dedication and determination of the people themselves. Mr. Myrl Roberts was in charge of our plant operations and productions of nutmeats from the very beginning. Myrl was with my father in 1946 in Knoxville, Tennessee to look at machinery built by Smalley Manufacturing Company. After Dad agreed to buy the machinery, he and Myrl started driving home and Dad asked Myrl, "Do you really think we can make it work?" So Myrl looked Dad straight in the eye, paused and in great seriousness stated, "Well, Ralph, you've bought it so now we've GOT TO MAKE IT WORK!" That's the way it's always been in the Hammons Company - - if we start it, we've got to make it work. Kenneth H. Howard, a highly skilled machinist, was a son-in-law of the inventor, Mr. Smalley. Ken Howard became a close friend to my father and Ken joined the company in 1948. He brought new ideas for cracking and processing the hard nuts and from 1948 to 1953 Ken Howard, Myrl Roberts, and my father together designed and built three new cracking machines. These machines have been over-hauled and modified many times but we're still using the basic cracking machines today - - because we've never found a better way to do it. When Dad and the industry recognized the need for a machine to remove the outer soft hull in order to buy enough nuts in the shell, again Ken Howard, Myrl Roberts and father found a way to do it, and they patented the new discovery and invention.

In 1954, Dad suffered a severe heart attack, which was thought to have been brought about by the stress from working twenty hours most days trying to make the business work. On several occasions, Dad had discussed the Black Walnut business with his brother-in-law and my uncle, Mr. Clarence C. Cavender. In fact, Clarence told me that Dad had tried to get him to join him in the business at the start, in 1946. Anyway, Dad asked Clarence to come to Stockton and keep business going until he recovered and could return. Clarence accepted the challenge and liked it so well he stayed until officially retiring from the business in 1977. A lot of credit for growing the business and the total industry must be given to Clarence. Clarence and I worked together in running the plant. I took care of nut meat sales and marketing. Clarence was in complete charge of all nutshell operations. He did the job! At 86 years of age, Clarence is still interested in seeing the company and the industry continue to grow.

As the second generation manager of business, I owe a lot to all the dedicated, hard-working people who have helped make it work. I sort of grew up in the business doing what I could to help in the summer months when school was out. My first paycheck was in June, 1948, at age 15. My job was to wash and dry the nut shell that had been discarded and bulldozed down the hill behind the plant. Dad wanted to recover that shell to grind in a hammer mill and sell to powder companies for making dynamite. That was the beginning of our nut shell division. For the first several years the shell was strictly considered to be a by-product from cracking and processing nuts. But now the shell business is really a separate industry of its own. It has become a very major part of our business.

In 1969, I invited Mr. Gus S. Rutledge, to my office to discuss planting new Black Walnut trees to increase our supply of nuts for processing in the future. Gus soon joined the company and was in charge of our public relations in agriculture, which included growing new trees. Gus possessed many talents and later was in charge of buying all nuts to be processed as well as heading up our nut shell division. Gus retired in1996, but he continues his keen interest in the business.

Dad's brother, Ferrell O. Hammons, retired from the company in 1973. He had been in charge of buying nuts in the shell. At his retirement party, I announced that Ferrell had bought enough Black Walnuts in the shell that if all the nuts that he bought were loaded in one-hundred-thousand-pound rail cars, it would take a train 60 miles long to haul them all. That was in 1973, and we bought and processed nearly one-half billion pounds of nuts since that time. Certainly Ferrell Q. Hammons did a lot to help in the success of the company.

Certainly there are many other persons, each in his own way, that have all played a part in making the history of the Eastern Black Walnut industry as it is today.

Status Report On The Eastern Black Walnut Nut Industry, Nut Markets, By-Products, And Future Challenges

Brian K. Hammons
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Stockton, Missouri

OVERVIEW

Eastern Black Walnuts are unique among the world's tree nuts. The native American nut, known among customers only in the United States, produces annual harvests that are only a fraction of all tree nuts including almonds, walnuts (English), pecans, hazelnuts, cashews, pistachios, brazil nuts, macadamias, and even pine nuts.[1] With the black walnut's much lower yield of nutmeats, the total annual consumption is about 2-3 million pounds, or less than .1% of the other tree nutmeats.[2]

While the production volume is relatively small, the rich, distinctive flavor of the Eastern Black Walnut makes it a true delicacy. That robust flavor enhances many foods as an ingredient (not snack) nut. Annual consumption is growing steadily, markets for nut shells and uses for other by-products are growing, interest is growing outside the United States, and the future looks bright.

The following paragraphs discuss these areas of the black walnut nut industry:

- Markets for Black Walnuts nutmeats;
- Uses for nut shells and other by-products; and
- Challenges and opportunities for future growth.

BLACK WALNUT NUTMEAT MARKETS

Eastern Black Walnuts are used all over the United States in baked goods, ice cream, and candies. While the strongest consumption is in the natural growing regions, the midwest and east-central states, consumption is also strong in places like Florida and Arizona with large numbers of people who come from the natural growing regions.

Presently about 2 million pounds of black walnut nutmeats are used each year. The greatest volume still is used in **home baking.** Traditional recipes such as cakes, cookies, pies, and nut breads, along with new recipe ideas that use the unique flavor in items such as salads, side dishes, and entrees, provide a stable base for usage of black walnuts. This is greatest during the fall months as holiday baking consumes almost half the annual usage. The trend for fall consumption provides opportunities for exposure and promotion, but it also makes the nut business very seasonal. Most

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[1] 1997 Worldwide harvests for Tree Nuts were as follows:
Almonds - 969 million pounds (shelled); Walnuts (English) - 1,375 million pounds (in shell); Pecans - 375 million pounds (in shell); Hazelnuts - 1.406 million pounds (in shell); Cashews - 2,156on pounds (kernels); Pistachios - 425 million pounds (in shell); Macadamias – 36 million pounds (shelled); Black Walnuts (Eastern) – 29 million pounds (in shell)
Source: "World Consumption and Production Trends", published by International Nut Council, July, 1998; Hammons Products Company.

[2] Black Walnuts average about 8% yield for wild nuts (based upon purchased wet weight). Other tree nuts average 40% to 60%. Applying these estimates, other tree nuts produce over 4.5 billion pounds of nutmeats.

of the baking nuts are sold in food stores under a variety of name-brand labels in package sizes from 2 ounces to 20 ounces. In the future, as people bake less and eat out more, the industry must promote increased usage of black walnuts in restaurants and other food service outlets.

Ice cream is one food in which people enjoy black walnuts year-round, especially during the spring and summer months. Black walnut ice cream is very popular in many regions of the United States. Some companies report it ranking as high as 3rd on the flavor list. About 40%, or 800,000 pounds, of black walnuts are used every year in black walnut ice cream. Familiar brands include Baskin-Robbins, Blue Bell, Braum's, Edy's, Hiland, Mayfield, Belfonte, Yarnell, Barber, and many others. The ice cream market is growing, as each year more companies make black walnut ice cream. New flavors such as black walnut fudge and black walnut oatmeal cookie ice cream will help further growth.

Candies including fudge, brittle, and high quality chocolates create a special blend of sweetness with the robust black walnut. Many small candy makers in the midwest and eastern U.S. have loyal customers who love their black walnut items, but the high cost of the nutmeat has kept most large confectioners away.

Black Walnuts are not just tasty, but they also can be very nutritious. While most of the calories are from the oils and fat, there is no cholesterol.[3] Almost all the fat is unsaturated, both mono- and poly- unsaturated, which are associated with a healthy diet. Black Walnuts are nutritionally similar to other tree nuts, for which research is demonstrating some very positive health benefits including reduced risk of heart disease[4] and reduced levels of blood cholesterol, particularly LDL ("bad") cholesterol.[5] Much research remains to be done to support the positive health benefits of nut consumption. As that research is undertaken and the results are publicized, the market potential for all tree nuts, including black walnuts, will increase significantly.

NUT SHELLS AND BY-PRODUCTS

Black Walnut Shell is among the hardest of all nut shells or seeds.[6] About 60% (wet weight) of the purchased raw black walnuts is shell, which results in about 12-18 million pounds of shell each year. Obviously, an economical use for the shell is critical to the success of the black walnut nut industry.

After the nut is cracked and the nutmeats removed, the raw shell is ground into six basic sizes for industrial uses. The primary use where hardness is important is **abrasive blast cleaning and polishing.** Jet engines, electronic circuit boards, jewelry, gun casings, musical instruments, engine parts, ships, and submarines all are cleaned with black walnut shell as a "soft grit abrasive." Cosmetics and soaps often contain nut shell for its abrasive action. The shell also is used extensively in **oil well drilling** as lost circulation material seals in fracture zones, which prevents loss of

[3] A ¼ cup serving of Black Walnuts contains 190 calories, 150 of which are from fat, and no cholesterol. Of the 16 fat grams, 10are polyunsaturated, 5 are monounsaturated and only 1 is saturated.
Source: Dr. Milton Bailey, University if Missouri, Department of Food Science & Nutrition.

[4] *See* Fraser, G.E., Sabate, J. , Beeson, W.L., Straham, T. M. : "A Possible Protective Effect of Nut Consumption on Risk of Coronary Heart Disease". Arch. Internal Med., 1992; 152: 1416-24.

[5] Sabate, J., Fraser, G. E., Burke, K., Knutsen, S. et al. "Effects of Walnuts on Serum Lipid Levels and Blood Pressure in Normal Men'" N. Engl. J. Med., 1993: 3 28:603-07.

[6] Black Walnut shell has a hardness (Moh's) rating of three and a Modulus Elasticity of 170,000 p.s.i. Other shells and seeds have a much lower elasticity of 10,000 + p.s.i., so they are not as durable.

pressure and drilling fluid when cracks develop in rock around the well. Finely ground black walnut **shell flour** is used as a filler in many products such as glue for plywood, dynamite, plastic and rubber products, and in castings to make figurines.

The market for black walnut shell is good. It is known by many users as the best media for abrasives and lost circulation material. English walnut, pecan, or other shells can supplement the supply when black walnut shell is not available, which keeps the prices competitive. Still, the hard shell is a very important product of the black walnut nut industry. As Gus Rutledge used to say, because of the shell "the black walnut affects every man, woman, and child in the United States every day."[7]

Oil Stock is a by-product of the nut cracking and processing that is used in animal feeds. The meal and dark nutmeats from the black walnut provide a feed that is high in energy because of its fat content, and also is a good source of protein. About 2 million pounds is produced each year and used by farmers and feed producers located near the black walnut shelling plants.

Hull, or the green/black outside husk of the black walnut, is not presently marketed extensively. The hull is typically removed at the nut buying stations and is spread on pastures or other land areas where it oxidizes quickly. It can be used as a natural stain, but the water-weight and handling make transportation unfeasible. There are some interesting potential uses for black walnut hulls that could create markets for some of the hull, including medicinal applications or nutrition supplements. More research is needed, however, before the benefits can be proven and any markets developed.

Black Walnut Oil has potential but is not being produced or marketed at this time. Research has been done on extracting edible oil, and preliminary surveys show some interest in the flavorful nut oil for use on salads and other foods, much like olive or other nut oils. The nutrition profile is positive and the flavor seems to have some appeal. More extensive market research will determine whether black walnut oil has real potential as a profitable by-product of the black walnut nut industry.

FUTURE CHALLENGES AND OPPORTUNITIES

The future of the eastern black walnut nut industry is exciting. The industry is small but is seeking to improve in all areas from tree cultivation and nut production, to nut hulling, handling, drying, and processing, to promotion and marketing of black walnut nut products. Due to the small size and lack of large economic rewards, progress is slower than for other tree nut industries with much larger crops and yields.

One major challenge is **nutmeat yield.** The average wild-crop yield is only about eight percent (8%). This means that 100 pounds of nuts that cost $16-$18 ($.16 - $.18 per pound including hulling and freight) will produce about 8 pounds of nutmeats. By the time shelling plant costs and selling expenses are added, the market price of the black walnut is much higher than other nuts, which inhibits both market growth and ability to pay more to the grower or harvester. The yield is even worse in some years, as low as 6.5% on purchase weight, which makes the economics even more challenging. The major opportunity from this is to increase the nutmeat yield, which can be done

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[7] Gus Rutledge is a former Vice President of Hammons Products Company, promoting Black Walnuts since 1972.

with careful nut procurement practices, better hulling/handling systems, improved shelling plant efficiency, and harvesting nuts from managed trees that produce superior-yielding nuts.

Another major challenge is **nut supply instability**. From 1994 through 1998 the supply of wild eastern black walnuts was adequate to meet the increasing market demand. The industry was blessed with an average of 27 million pounds in-shell during those five years, a dramatic increase from the previous three years. The 1998 wild crop, however, was only about 11 million pounds, putting pressure on supply until the fall 1999 harvest. The ability to procure consistent and ever-increasing supplies of nuts from wild trees is a very real long-term challenge to continued growth of the industry. The challenge is met partially by procuring wild nuts from a wide area. Although Missouri produces the most nuts, up to 18 states produce enough wild black walnuts to support buying stations. The long-term opportunity is to develop managed orchards that can consistently produce significant harvests of superior-yielding nuts. For those higher-yielding nuts a higher price could be paid which would produce a better incentive and return on the investment for the orchard growers. For example, if a grower produced black walnuts that averaged 20% hand-test yield, all fancy grade, and if all nuts were cleaned with moisture less than 4.5%, then that grower could be paid perhaps $.20 to $.25 per pound, a much more attractive price than the current $.10.

A third major challenge is the **lack of familiarity with the flavor of the nutmeat.** This is partially due to the regionality of the wild nut and partially to the small size of the industry with few marketing/promotion funds. Also, traditional consumers who loved the distinctive flavor lived in the black walnut growing regions, and perhaps picked up nuts themselves, but have succumbed to mortality (many have grown old and died). However, efforts to educate new generations of consumers through package design, recipe promotion, new product formulation, and public relations are meeting success as shown by the increased consumption over the past 8 years. Food trends moving toward rich, robust flavors and interest in "new" flavors with some tradition, also present opportunities for eastern black walnuts. Finally, oversees markets present fascinating new possibilities, as people in Germany, Japan, and other countries have shown interest in the flavor - - but this will take some time and market development.

SUMMARY

The eastern black walnut nut industry is relatively small and obscure among tree nut industries of the world. It only exists in the United States. Its source of supply is wild nuts harvested by hand. Its product often is confused with the more common "walnut" even by people in the natural growing regions. These are not problems; rather, they are opportunities for the industry to grow and develop further.

Those who work with black walnuts are entrusted with stewardship of an amazing resource. The industry traces back to the first native Americans who ate the wild nuts. It has grown with foresight, ingenuity, and leadership. And it will continue to thrive and grow into the next century, facing challenges and opportunities with the same spirit and optimism that fueled its early years.

The status of the eastern black walnut nut industry is good. The greatest is yet to come!

For more information, check the black walnut website on the internet at:
www. hammonsproducts.com

Social Aspects of the Eastern Black Walnut

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Burdened with fluctuating economies and expanding urban development of our rural landscapes, we need to focus on places and efforts that support rather than fragment our lives; places and efforts that balance the hard, standardized, and cost-efficient with the natural, personal, and healthful. (Gallagher, 1993) The unique dual path of the wild and commercial eastern black walnut industry is already providing opportunities for balance in our increasingly complex lives.

This chapter is provided to encourage the reader to sit back and examine the beneficial aspects of the eastern black walnut in terms of long-term economic stability for communities and/or regions, infrastructure to support the industry, and the inherent desire for people to have a balanced relationship with the environment.

LONG-TERM ECONOMIC STABILITY FOR COMMUNITIES

With national trends moving in the direction of less agricultural farmland and more urban growth, the potential impact upon major eastern black walnut producing areas such as southwestern Missouri could be significant. The types of people moving into these rural areas are in many cases not familiar with the rich culture of the region, nor are they aware of the potential of crops such as eastern black walnuts. "Putting land into eastern black walnuts is a good way to invest in future generations, as well as a natural and good thing to do with newly acquired property." (Dilsaver, 1998)

According to a 1995 Gallup Poll study (Wolfe & Chambers, 1995) commissioned by Southwest Missouri Resource Conservation and Development (RC&D), over 4 out of 5 (82%) landowners viewed "beauty or nature appreciation" as being a somewhat or very important reason to own their wooded land. Also, "keeping the land in your family" was an important consideration. People inherently like to have trees on their property. More than 1/3 (37%) of landowners surveyed intended to plant trees on their land, and almost 2/3 (65%) of landowners stated that if provided with trees, they would plant them.

Planting eastern black walnuts on suitable property would provide aesthetic beauty, as well as a valuable long-term investment in the future. Approximately one out of ten (11%) surveyed landowners said they would be willing to pay for forest management services. New, higher yielding strains of eastern black walnut are being patented and planted throughout the eastern black walnut growing region of the U.S. as well as other continents. As the interest in eastern black walnut grows, so will the industry as a whole.

INFRASTRUCTURE TO SUPPORT THE INDUSTRY

The eastern black walnut industry will follow two paths. One will be the continued usage of the wild crop, so we will need to continue to focus attention and appreciation for the multiple inherent values provided by a "free" natural renewable resource.

The second will be a commercial extraction, but people must be reminded to value and appreciate the importance of balance, harmony, economy, renewability, and sustainability of this unique tree crop. Although not "wild" or "natural" in the traditional sense, a planted field of medium size eastern black walnut trees spaced 20 feet by 40 feet apart can be a peaceful and beautiful place to visit. Psychologists have shown that even short visits to city parks contribute to improved moods (Hull, 1992). Relaxation and stress reduction occur when people are viewing natural landscapes (Ulrich, 1981).

Companies like Hammons Products in Stockton, Missouri invest a portion of their yearly revenue into research and development to come up with new and better ways of growing and processing eastern black walnut. Ways that also take into account the social aspects of this unique tree crop. Hammons currently has three plant materials patents on three different trees selected for their very high nut yielding capacity. It is these types of efforts that will enable the eastern black walnut industry to grow and thrive in the future.

INHERENT DESIRE FOR PEOPLE TO HAVE A BALANCED RELATIONSHIP WITH THE ENVIRONMENT

Each unique type of landscape is often also the location of a unique cultural meaning for humans that share that landscape. "A sense of place is part and parcel of the effort to find meaning in the land and to create personal and cultural identities. Places in the landscape are infused with meaning and are more than the sum of their biophysical attributes or their associated plants, animals and landforms. The meanings associated with certain places obviously are derived from experiences in them, and these experiences are quite variable. They can come from growing up in a particular region, such as the flat openness of the Midwest, from listening to grandparents and relatives describe their lives on the family farm, or from adventure experiences traveling the wild rivers of the West. These personal experiences are tied to other people and their lives, to ways of life and play, and to a culture that has been greatly shaped by the natural environment." (List & Brown in Driver et al, 1996, p. 461-462)

The influence of black walnuts in southwestern Missouri is a classic example of culture shaping around nature. A culture all its own has grown up around a basically wild crop. Generations of families each Fall have put tiny and adult sized hands to work gathering the pungent, fleshy nuts on their farms. Nuts from trees are sometimes considered a nuisance, but more often a field full of fallen wild black walnuts is considered a great source of charity funds or spare holiday gift money. Gathered nuts are processed at hulling stations provided by black walnut processing plants such as Hammons Products Company in Stockton, Missouri. The hulling machines pry and rub the thick fleshy husk off the nuts, and then they are bagged and weighed. A typical pick-up load of 600 pounds of nuts can yield a nice sum of money. Three generations together at a hulling station realizing the benefits of their efforts from collecting black walnuts on the family farm is a common sight.

To ignore this sense of place and culture is to ignore the people, ideas, and the meanings that are attached to these places. These meanings and ideas are as important as the biophysical attributes of specific landscapes and ecosystems. It is important that landowners consider the psychological and spiritual consequences of their land management decisions in addition to the economic, scientific, and environmental consequences. The eastern black walnut provides the opportunity for landowners to establish a balanced relationship with the environment as well as a solid long-term investment in future generations, both economically and spiritually.

REFERENCES

Dilsilver, Frances (1998). Personal communication with Management Forester with the Missouri Department of Conservation, Republic, Missouri.

Gallagher, Winifred (1993). *The Power of Place: How our Surroundings shape Our thoughts, emotions, and actions.* Poseidon Press: New York, NY.

Hull, R. IV. (1992). Brief encounters with urban forests produce moods that matter. *Journal of Arboriculture,* 18, 322-324.

List, Peter & Perry Brown (1996). *In Nature and the Human Spirit- Toward an Expanded Land Management Ethic.* Edited by B.L. Driver, Daniel Dustin, Tony Baltic, Gary Elsner and George Peterson. Venture Publishing, Inc. State College, PA.

Ulrich, Roger, (1981). Natural versus urban scenes: Some psychophysical effects. *Environment and Behavior,* 13, 523-556.

Wolfe, Kent L. & Gregory Chambers (1995). *Southwest Missouri Resource Conservation and Development, Inc. – Wooded Landowner Study* (unpublished study). Prepared by the Gallup Organization: Princeton, NJ.

Economics of Eastern Black Walnut Agroforestry Systems

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Fifteen cents doesn't go far these days, unless it has lots of time. For instance, if you invested 15 cents at 8% interest compounded annually over 60 years you, or your grandchildren, would eventually collect more than $50. That's the power of money over time. At the same time, if you spent 15 cents today and had to wait 60 years to get a return on it, you must receive at least $50 to get your money's worth at 8%. So, who is going to spend 15 cents today and wait 60 years for a payoff? If you have planted a tree seedling with the intention of growing a fully mature timber tree, you already have made such a commitment. That seedling probably cost you 15 cents and perhaps more. If it was more, you must receive more than $50 in 60 years to cover your minimum expected return of 8%.

An easy way to visualize the power of money over time is to recall the old story of the blacksmith and the chintzy horse owner. The owner had the blacksmith shoe his horse. When he went to pay the bill, the smithy said he wanted $100 for the job. The owner thought that was totally outrageous and told the smithy so. The smithy, being a reasonable and clever man, offered an alternative.

"I'll tell you what I'll do. I put 32 nails in those horseshoes. You pay me a penny for the first one, two cents for the second, three cents for the third and so on until you have paid for the 32 nails and we'll call it even." The horseman didn't hesitate and jumped at the opportunity to pay only pennies per nail. Of course, when he learned that the constant doubling of the price would eventually add up to millions of dollars, he reneged and gladly paid the $100.

To offset the effects of time we can take two approaches to our tree plantation systems that will offer a higher return on our investment. We can reduce as far as possible the amount of money we invest in the early years. However, we must be careful not to cut costs to the point of reducing income from the trees later on. Some added costs in the beginning such as regular herbiciding and investment in quality seedlings definitely will pay off in later years.

The second alternative to offsetting long-term costs is to design a system that also has income as soon as possible. This early income offsets the early costs. Many agroforestry practices such as alleycropping and silvopastoral systems where livestock graze the alleys offer this early income opportunity.

What has become known as the "Missouri Basic System of Agroforestry" is typical of these multifaceted systems.

THE MISSOURI BASIC SYSTEM

Because every practitioner's system will be different in some way, it is necessary to create a baseline or model black walnut agroforestry system to compare with.

The "Missouri Basic System of Black Walnut Agroforestry" essentially is that system that was demonstrated by Gene Garrett, director of the University of Missouri Agroforestry Center, at the Sho-Neff Plantation at Stockton, Mo. and was adopted by HarperHill Farms and others around Missouri and Midwestern states. In its simplest form it is a forage/nut/timber system where the forage is harvested for hay. This basic system is used as a model because it is the one (with many slight modifications) that has been most widely accepted by landowners.

(See Black Walnut Agroforestry--Missouri Basic System for outline of practices and costs and returns.)

Profitability under the Missouri Basic System of agroforestry begins and ends with the walnut trees. In most cases, the sustained profitability of the enterprise will almost totally depend on nut production. Accepting that premise dictates that management priorities for the system be directed toward the tree crop, not to the supporting or alley crops.

It simply means that when a decision must be made that will favor one or the other, the walnut trees and the resultant nut crop will receive first consideration.

However, income from secondary enterprises such as hay, livestock, row crop or between-the-row or between-the-trees crops play a most important role of providing cash flow, especially during the first 10 to 15 years. From the standpoint of return on investment, these interplanted crops with their annual up-front incomes have a major effect on reducing the costs of accumulated interest on the first-year investment in seedlings, planting, grafting and other maintenance costs.

When an agroforestry system is analyzed for profits and return on investment over a 60-year period, it becomes obvious that high initial establishment costs severely reduce average annual percentage return on investment. The 60-year analysis is used because it is at that point that the 8 to 9-foot butt log is mature and can be cashed in for nearly full value. It is at this point in the life of the plantation that the landowner will be faced with a critical economic decision--Is the log market such that cutting and selling the logs and investing the income at current rates more financially attractive than the expected annual net income from continued nut harvest. The landowner also will have to take into consideration the increased risk of loss of the log value to natural disasters such as disease, fire and lightning.

But we have the luxury of postponing that decision for 60 years. Most likely our children or grandchildren will bear that burden. Our concern is more immediate. Will a black walnut agroforestry system make money now or within a reasonable time? The answer: An unequivocal "Yes."

DETERMINING COSTS AND YIELDS

In practice, black walnut agroforestry will have different profitability potential for every practitioner depending on their individual financial circumstances and how the agroforestry system fits into the overall farming operation.

Black walnut agroforestry farming systems are a relatively new concept. The oldest established systems now are only a quarter century old. Therefore, the economic information available for making profitability analysis is limited. In many cases it is necessary to project yields of nuts and log values based on wild, native tree production in non-plantation settings. However, there is enough accumulated data from individual nut yields on trees of various ages, both wild and grafted, that conservative yield projections can be made with some confidence.

Costs associated with production practices are fairly well established. Records from the plantations established at Hammons Products Company's Sho-Neff Plantation at Stockton, Mo. for the last 25 years and from HarperHill Farms at Butler, Mo. for the past 13 years offer reliable and current information (see attached cost references). Future costs such as those for mechanical nut harvesting (see separate chapter) are taken from similar costs for pecan harvest and from experimental walnut harvesting trials.

To determine profitability of a farming system it is necessary to analyze the costs and income over the lifetime of the crop. For an annual crop such as corn or soybeans it is a rather simple process because there are only single-year costs and incomes to calculate. For a perennial crop such as black walnut and supporting crops such as forages in the alleys, the calculation is more complex because of the cumulative effects of costs and income, especially in the establishment years.

The 60-year analysis also is useful for making comparisons of profitability between agroforestry systems. A simple change such as switching from planting bareroot seedlings and field grafting in the third year to planting nursery-grafted seedlings can have a major effect on the landowner's rate of return on investment over the long term.

IS IT PROFITABLE?

Black walnut agroforestry is a commitment--a long-term commitment. Most likely, as in the example of the Missouri Basic System, from 10 to 15 years will be required before a net profit is realized when interest on the investment to establish the plantation is figured in. However, when the return on investment over a long period (60 years) is considered, the investment can be highly profitable. When compared to a similar investment in a mutual fund over many years the rate of return on the agroforestry system of 10 to 20% or more is very competitive.

When the Missouri Basic System was analyzed for long-term profitability, it was determined that it had an Internal Rate of Return, or an annual return on investment in the case of a mutual fund, of 17%. That's projected over 60 years. The analysis also indicated that if you expected an 8% return on your investment you could pay $620 an acre for the land used in the system. Remember, the Missouri Basic System is based on rather conservative yield and income estimates. And, it includes a $7 an hour labor charge for all production practices.

As a comparison, the profitability of the Missouri Basic System without a nut crop was made. While the Internal Rate of Return was still a respectable 12%, the amount a landowner could invest in land at an expected return on investment of 8% was only $75 an acre. In short, this system would not pay for itself. However, some landowners would find this quite acceptable since they already own the land and might find an agroforestry practice suited their needs and fit their overall farming plans.

A third comparison was made where the trees were grown for timber only and neither nuts nor hay was harvested. In this case the Internal Rate of Return dropped to less than 3% and the land investment at an expected 8% return dropped to a negative $245 per acre.

To illustrate that every agroforestry operation will express unique profit potential because of varying input costs and selection of differing production practices, an analysis of the Missouri Basic System was made with the assumption that the operator owned the harvesting machinery and was using it to harvest 300,000 pounds or more of nuts each year. This level of nut harvesting reduces the harvest equipment ownership costs to a minimum. In this case the Internal Rate of Return was increased to 20% a year and the landowner could have invested $943 an acre in his land at an expected 8% return.

RATE OF 32% NITROGEN PER ACRE IN OUNCES										
Radius (ft.)	Area (sq.ft.)	30 lbs.	40 lbs.	50 lbs.	60 lbs.	70 lbs.	80 lbs.	90 lbs.	100 lbs.	150 lbs.
2	13	0.48	0.64	0.8	0.8	0.96	1.12	1.28	1.44	2.08
3	28	0.96	1.28	1.6	1.92	2.24	2.4	2.72	3.04	4.64
4	50	1.6	2.24	2.72	3.36	3.84	4.48	4.96	5.44	8.32
5	79	2.56	3.52	4.32	5.28	6.08	7.04	7.84	8.64	13.12
6	113	3.68	4.96	6.24	7.52	8.8	9.92	11.2	12.48	19.2
7	154	5.12	6.72	8.48	10.24	11.84	13.6	15.36	17.6	25.6
8	201	6.72	8.8	11.04	13.28	15.52	17.6	20.8	22.4	33.6
9	255	8.48	11.2	14.08	17.6	19.2	22.4	25.6	28.8	41.4
10	314	10.4	10.4	17.6	20.8	24	27.2	32	35.2	51.2
11	380	12.64	17.6	20.8	25.6	28.8	33.6	38.4	41.6	62.4
12	452	14.88	20.8	25.6	30.4	35.2	40	44.8	49.6	75.2
13	531	17.6	24	28.8	35.2	41.6	46.4	49.6	59.2	88
14	616	20.8	27.2	33.6	41.6	48	54.4	60.8	67.2	102.4
15	707	24	32	38.4	46.4	54.4	62.4	70.4	78.4	116.8
16	804	27.2	35.2	44.8	52.8	62.4	70.4	80	88	132.8
17	908	30.4	40	49.6	60.8	70.4	80	89.6	100.8	150.4
18	1018	33.6	44.8	56	67.2	78.4	89.6	100.8	112	168
19	1134	36.8	49.6	62.4	75.2	88	100.8	112	124.8	187.2
20	1257	41.6	56	68.8	83.2	97.6	110.4	124.8	139.2	208

MEASURING HERBICIDE SPRAYED AREA

(Acres/100 feet sprayed on both sides of tree row)

(Formula: 2 times spray width time 100 divided by 43,560 equals acre per 100 feet of row)

(Spray width)
1-foot width = .0046 acre/100 feet of tree row
2-foot width = .0092 acre/100 feet of tree row
3-foot width = .0138 acre/100 feet of tree row
4-foot width = .0184 acre/100 feet of tree row
5-foot width = .0230 acre/100 feet of tree row
6-foot width = .0276 acre/100 feet of tree row

Calculating actual sprayed area per acre based on 40-acre field with rows 40 by 20 feet: 1 quarter-mile row=1,320 feet minus turn rows (area at ends of field to turn equipment from 20 to 40 feet without trees planted) times 2 (two ends)=40 to 80 feet=1,240 feet (80 feet of turn row area) times 3-foot spray strip=.0138 (from table above) times 1,240 feet of sprayed length of row divided by 100 feet=1.24 times .0138=.017 acres (almost 1/5 acre sprayed per quarter mile of row). There are 33 rows in a 40-acre field a quarter mile long laid out on 40 by 20 spacing. So, 33 rows=.017 (acre/row)=5.6 actual acres sprayed or only 14% of the total field.

PART 2

ESTABLISHING THE WALNUT PLANTATION

Characteristics Of Good Growing Sites For Black Walnut

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Abstract: Black walnut (Juglans nigra L.) occurs as a minor component in stands of mixed deciduous forest in the eastern United States. Black walnut grows on a variety of soil textures and landscape positions, but grows best on soils having good drainage, aeration, moisture availability, and fertility. Areas being considered for planting walnut should be thoroughly investigated for site quality for the species before planting. Soil and site requirements for locating black walnut planting sites are presented.

Eastern black walnut is very demanding when it comes to site conditions required for good growth. It typically grows as scattered individual trees or in small groups throughout the central and eastern parts of the United States and southern Ontario. Black walnut can survive temperatures as low as -45°C in some areas of its natural range (Fowells 1965). It is genetically variable in growth and survival (Bey 1980; Funk et al. 1981).

Site selection should rank at the top of the walnut grower's list of important things to do when deciding to plant black walnut. The value of walnut wood has more to do with the number and size of high quality logs than with the amount of fiber produced. Good height growth is essential for extra logs and good diameter growth is essential for high value-logs. Neither good height growth or good diameter growth can be obtained on poor quality land.

Information on how soils affect black walnut nut production is lacking. However, because nut production is a nutrient- and moisture-drain on the tree, soil characteristics that encourage good growth and wood production, should also be important for nut production.

It would be very convenient for the potential walnut grower to select areas to plant if the "good and bad" soils for growing walnut in a county were identified and located on a map. Soils in Illinois, southeast Minnesota, Iowa, and Indiana were classified as suitable, questionable and unsuitable for growing black walnut (Losche et al. 1980, Ponder and Johnson 1984, Ponder and Johnson 1986, Ponder et al. 1989). But because all soils are not good or bad for the same reason, they should be evaluated individually with an on site investigation, even when the soil description indicates favorable characteristics for growing the species.

WHAT ARE THE IMPORTANT SITE REQUIREMENTS?

Black walnut will grow on a wide variety of soils and landscape positions (Table 1), but more important to the grower is the growth rate on each kind of soil. It grows best on deep, well-drained, nearly pH-neutral soils that are fertile and moist, but not wet. It should be protected against wind and against spring and fall frost. The most favorable sites are in well-drained bottomlands (Losche 1973). The better walnut sites on upland topography are located in the lower north- and east-facing slopes, in coves, and along narrow streams. South-facing slopes and narrow ridge tops are poor walnut sites because soils are often dry, shallow, and highly susceptible to erosion. The soil must have good internal drainage and aeration. Avoid areas that remain flooded for 3 days or longer.

SOIL DEPTH

The soil profile on good black walnut sites should be at least 3 feet deep without obstructions that may affect the development of the root system. Shallower soils will not hold enough water to support satisfactory tree growth. Also, the grower must realize that even the 3-foot depth could limit growth and the final product to be harvested (Table 2). An effective soil depth of 5 feet (without restrictive layers) would better ensure plenty of room for root system development and water storage.

SOIL DRAINAGE

Excessively drained or poorly drained soils are unsuitable. These soils restrict air movement, inhibit root growth, and reduce tree height and diameter (Table 3). Soils that are poorly drained or have a high water table are likely to have an unpleasant odor and a blue or drab color composed of a mixture of gray and blue called mottling. Avoid soils with these colors or conditions within 2.5 feet of the soil surface. Soils with good internal drainage usually are brown, reddish brown, or yellowish brown.

A complacent attitude shouldn't be assumed if a new plantation is showing good growth. Hidden site problems may not express themselves until a much later age in the life of the plantation. It sometimes takes five or more years for the root system to be substantially affected by soil characteristics hidden below the surface. As a young walnut tree ages, its root system must develop properly. If during this period, a stratum of rock, gravel, fragipan, heavy clay or poorly drained soil is encountered, this development is restricted, resulting in the loss of vigor. The nearer to the surface the restricting factor is located, the sooner it will be evidenced by reduced top tree growth.

SOIL TEXTURE

Soil texture affects soil water-holding capacity, influences the ease at which water moves into and through the soil, and root penetration. A soil's texture is determined by the amounts of sand, silt, and clay particles it contain. Ideal soil textures include loam, sandy clay loam, silt loam, and clay loam (Table 1). Soils with moderately fine textures (more silt than clay or sand), such as a silt loam, will generally have sufficient amounts of nutrients, yet will be reasonably well drained. Sandy soils often are low in nutrients and are excessively drained; heavy-textured soils, such as clays, may limit water movement and root growth of black walnut. The intermediate textured soils such as the loams have better moisture holding capabilities combined with good aeration. A loam textured soil also has the best structure (arrangement of soil particles to form aggregates or peds) because of the various sizes of particles, even in a loose structure, have large pores between aggregates allowing for both moisture and aeration. Good planting sites also include limestone soils with silt loam over clayey subsoil and deep rocky soils unsuited for cultivation because of their rockiness.

SOIL NUTRITION

Black walnut is demanding in terms of soil nutrients. The size of the soil particles affects the availability of nutrients. In general, finer textured soils provide more nutrients than coarser soils. The nutrient requirements of black walnut are generally the same as it is for non-irrigated corn. The pH of the soil helps to regulate nutrient availability. The upper 6 inches of the soil should have a pH of 6.5 to 7.2 (Table 4). It is recommended that the surface soil (A horizon) has an organic matter content near 3.5 percent and has an adequate supply of nutrients (Parker et al. 1992). Fertilization is usually not needed or recommended at the time of planting. The money will be better spent if used to add limestone to correct the pH and to provide 3 to 4 years of weed control. Eliminating grasses or preventing their development within 3 feet of the trees until crown closure will reduce competition for nutrients and moisture, thereby creating an ideal condition for tree growth.

CLIMATE

The local climate is an important part of the site. Avoid low areas where cold air settles at night and might cause night frost in late spring or early fall. The cold air drainage problem becomes worse near the northern part of black walnut's distribution range. In such cases, the warmer southern slopes may be more favorable than the northern cooler slopes. Avoid areas that may be subject to unusual night frost. However, these areas may not be easily identified. Avoid sites that are noted for late spring frosts. In the northern part of walnut's distribution range, plantation success may be enhanced by planting seedlings developed from seed of cold hardy parents (Li et al. 1992). Cold hardiness in black walnut is under strong genetic control (Parrot 1971).

Wind affects the establishment of black walnut. Seedlings planted in level, windswept, open fields are less vigorous, have smaller leaf areas, and suffer more foliage damage than those planted in similar soils in either forest openings or protected fields (Schneider et al. 1970). The impact of wind on nut production is not known.

SITE IMPROVEMENTS

Can black walnut be grown successfully on land that lacks one or more of the recommended characteristics of suitable soils for growing black walnut? Several practices have been tried in an effort to increase the productivity of marginal sites. Most attempts such as fertilizing sites believed depleted of nutrients and refilling deep trenches and title drainage in poorly drained soil have resulted in limited success. An alternative to fertilization may be to interplant with nitrogen-fixing plants (Van Sambeek and Rietveld 1981). Also, planting companion trees and forage legumes on walnut sites may provide an alternative to chemical weed control.

Cultural practices designed to increase soil moisture might promote walnut growth. These practices include irrigation, terracing, mulching, and control of undesirable moisture using vegetation. Practices designed to improve subsoil drainage and aeration might include surface and title drainage and, in addition, deep tillage may promote better rooting in the subsoil.

Prevent mistakes, get help. Soil survey reports are available for most counties where black walnut can be grown and can be obtained from local Natural Resource Conservation Service Centers. They are the best source of information for judging the suitability of a site for black walnut. They contain detailed map of soil units with descriptions of each soil including woodland suitability groupings for different tree species. A pre-planting soil analysis and soil survey will reveal the presence of limiting nutrients as well as other undesirable soil features and prevent much frustration and delayed hope.

The local district foresters with the Missouri Department of Conservation are another good source of assistance. They can help interpret the soil survey report and provide additional assistance on site selection. In many instances, they are familiar with the species/soil relations for the soils in the district.

The other tool needed for checking the soil on the site is a shovel or a soil probe. Findings should be compared to the recommended site requirements for black walnut. When properly interpreted, the combination of site requirements and the characteristics of the site being investigated should yield success in selecting the ideal black walnut planting site.

REFERENCES

Bey, C.F. 1980. Growth gains from moving black walnut provenances northward. J. For. 78:640-645.

Fowells, H.A. 1965. Silvics of forest trees of the United States. U.S Dep. Agric. Agric. Handb. 271.

Funk, D.T., D. Neely, and C.F. Bey. 1981. Genetic resistance to anthracnose of black walnut. Silvae Genet. 30:115-117.

Li, P., L. Parrot, and J. Bousquet. 1992. Introduction of black walnut in southern Quebec: evaluation of 21-year-old full-sib families. Can. J. For. Res. 22:1201-1204.

Losche, C.K. 1973. Black walnut growth better on deep, well-drained bottomland soils. USDA For. Serv. North Cent. For. Exp. Stn. Res. Note NC-154, 3 p.

Losche, C.K., M.C. Clark, E.E. Voss, and B.S. Ashley. 1980. Revised guide to the selection of soil suitable for growing black walnut in Illinois. Spec. Pub. Northeastern Area, State and Private Forestry, Upper Darby, PA. 38 p.

Parker, D.J. Bockheim, and D. Meyer. 1992. Soil and site selection. Fact Sheet No. 68, Walnut Tips. Wisconsin Walnut Council.

Parrot, L. 1971. Le climat, facteur selectif, et l'adaptation genetique de Juglans nigra L., espece exotique au Quebec, Canada. Silvae Genet 20:1-9.

Ponder, F., Jr. and P. Johnson. 1984. Guide to selecting black walnut planting sites in southeast Minnesota. USDA SCS, Rochester, MN, 27 p.

Ponder, F., Jr. and P. Johnson. 1986. Guide to selecting soils for black walnut planting sites in Iowa. Iowa Conservation Com., For. Section, Des Moines, IA, 85 p.

Ponder, F., Jr., P. Johnson, and W. Beinke, 1989. Guide to selecting soils for black walnut planting sites in Indiana. Purdue Univ. Press. Purdue Agricultural Exp. Stn. Station Bul. 562.

Schneider, G., G. Khattak, and J.N. Bright. 1970. Modifying sites for the establishment of black walnut. pp. 155-169. In: C.T. Youngberg and C. B. Davey, eds. Forest Soils Conf., Raleigh, NC.

Van Sambeek, J.W and W.J. Rietveld. 1981. Seeding forage legumes in black walnut plantations. Walnut Council Bull. 8:6-8.

Table 1. Significant soil/site characteristics for black walnut growth

Soil/site characteristics	Suitable	Questionable	Unsuitable
Slope Exposure	North or east		South or west
Position on Slope	Middle, or lower with good drainage		Upper, or lower with poor drainage
Slope	0 to 15%	15 to 30%	>30%
Depth to bedrock, gravel or clay layer	> 3 feet	2 to 3 feet	< 3 feet
Drainage class	Well drained to moderately well drained	Somewhat poorly drained	Excessively drained, poorly to very poorly drained
Duration of flooding	Standing water up to 4 days in early spring		Standing water more than 4 days
Soil texture	Loam, silt loam, silty clay loam, silt, clay loam, sandy loam, sandy clay, fine sandy loam	Silty clay	Clay, sand, loamy sand, loamy fine sand

Table 2. Effect of depth to gravel layer on height and diameter at breast height (d.b.h.) growth of 25-year-old black walnut.[1]

Depth to gravel layer	Height growth	D.b.h. growth
	Inches	
< 40	34.1	3.9
> 40	51.4	6.4

[1]Losche, C.K.1973.

Table 3. Effect of soil drainage on mean height and diameter at breast height (d.b.h.) of 25-year-old black walnut.[1]

Drainage class	Depth to mottling	Height	D.b.h.
	---Inches---		
Well-drained	> 30	52.2	6.8
Imperfect	6 - 30	50.2	5.8
Poorly	< 6	47.1	5.3

[1]Losche, C.K. 1973.

Table 4. Recommended soil nutrient concentration ranges for suitable black walnut planting sites

			Anaylsis			
pH	Organic matter (%)	N(%)	P(lbs/a)	K(lbs/a)	Ca (lbs/a)	Mg (lbs/a)
6.5 - 7.2	2.0 - 3.5	0.25 - 0.3	60 - 80	225 - 275	2500 - 4000	300 - 600

Why Nut Evaluation?

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EARLY OBSERVATIONS

Early evaluations were based on visual observation with a descriptive analysis of the nut and usually the tree. For example, Thomas black walnut was discovered in 1881. It was described as being a prolific bearer, cracked much better than the average black walnut, and was larger in size and better flavored than other black walnuts. Kernel extraction was very good because of the roomy chambers of the shell. (5)

Other early descriptive terms used were as follows: A large nut; 19 nuts per pound; bears at an early age; thin shelled; cracks well; kernels easily extracted; kernels plump; good shell structure; and color and flavor of kernel is good.

These terms describe what the eye was seeing when the nuts and tree were compared to other native nuts and trees or other named cultivars.

JUDGING NUT SAMPLES

Judging nut exhibits at fairs and shows differs from evaluation contests. In exhibition judging, the classes are usually set up to include only a single cultivar or clone. The problem here is to judge a sample in comparison with the other entries of nuts of the same clone, and to rank these as 1st, 2nd, 3rd, etc. Here the schedule is concerned with such characteristics as size and uniformity of nuts in the sample, the color and attractiveness of the shell, and the color, plumpness, and quality of the kernels. In these exhibits, much depends on the showmanship of the exhibitor and the selective skills. The entry does not give information as to the intrinsic value of the clone as related to the other clones. (3)

The first judging schedule of points was devised by Professor E. R. Lake in 1915.

General Values:	
Size	10
Form	5
Color	5
Shell Values:	
Thinness	15
Cracking	20
Kernel Values:	
Plumpness	5
Color	10
Flavor	10
Quality	20
Total	100

Note: For insect or fungus injuries deduct 5-20 points.
Other score cards were established for chestnut, filbert, pecans, and Persian walnuts.

It was pointed out at the time that it was important at all times to have in mind the idea of working to keep the quality very high.

More recently, L.H. MacDaniels (4) offers a suggested judging schedule as follows:

JUDGING SCORECARD

	Points	Comments:
External Nut Characters:		
Size	15	The larger nuts are preferable.
Condition	10	Sutures not split. Not excessively dry. Free from fiber.
Color	10	Bright, attractive, not stained.
Uniformity	15	Uniform size.
Internal Kernel Characters:		
Plumpness	25	Plump, smooth, and free from high oil content (except chestnuts).
Color	10	The lighter the better.
Flavor	15	Not rancid or astringent, high in fat.

Upon comparing the two score cards the original card places 55% weight on external characters and 45% on kernel characters. The newer card places equal value on external and kernel values.

EVALUATION OF NUTS

Evaluation is a means of improving nut culture by finding, describing, and comparing the trees; which consistently produce abundant nut crops of superior quality. (2)

There are two parts necessary to completely evaluate a given clone. The first part is an evaluation of a sample of nuts according to an accepted schedule that will determine the relative merit of the sample of nuts. The second part of the evaluation has to do with characteristics of the tree itself, such as hardness, productivity, leaf health, branch angles, tree form, vigor, susceptibility to pests, regularity and volume of cropping, and response to propagation techniques.

In Nebraska, we have thus far limited our evaluation to ranking samples of nuts submitted by members and others either in-state or out-of-state.

We are using the Iowa scoring system, which we modified by adding taste as a factor of kernel quality. Our formula for scoring black walnut would be as follows:

> Final score = % kernel divided by (seal + appearance + usability + size + separation + pieces + kernel size + kernel color + kernel veining + shrivel + taste grade) X 100.

The reason taste was added to the scoring is the fact that the two score cards previously shown used taste as part of the scoring for shows. Also, in the survey of NNGA members conducted by Doug Campbell several years ago, eating quality ranked very high on the list of traits. (1)

Under the direction of Dr. Bill Gustafson, a scoring program called "NUT EVALUATION" has been devised. The raw data is fed into the IBM-AT Computer. The computer performs all of the calculations and will rank samples in descending order, from the highest score to the lowest score. It also prints out the various scores assigned by the grading committee so that a person can make comparisons between various samples. This makes it easy to convey the information to the newsletter, and saves much time in making hand calculations.

WHY EVALUATE NUTS?

1. It provides a method of finding new cultivars of superior quality.
2. It provides a method of rating named varieties in your area.
3. It is a good method to develop enthusiasm among members of a state association.
4. It is only as the nuts themselves have merit that other characteristics are worthy of further consideration.
5. Educational value of nut evaluation process and visual comparison of various nut samples.

REFERENCES

1. Campbell, R. D. 1979. What They Really Want to Know, Nut Shell, Vol. XXXIVI 10-11.
2. Hansen, Norman. 1968. Black Walnut Evaluation In Iowa. NNGA Proc. 59:45-50.
3. Lake, E. R. 1914. Proposed Score Cards for Judging Nuts. NNGA Proc. 5:19-21.
4. MacDaniels, L.H. 1979. Evaluating Nut Crops, Nut Tree Culture in North America. Pages 439-440.
5. Reed, C.A. 1920. Nut Culture in the United States. NNGA Proc. 11:38-39.
6. Bixby, WG. 1929. The 1929 Contest NNGA Proc. 22:42-70.

NUT EVALUATION ENTRY

Date____________________ Tree I.D. Number_____________

TREE DESCRIPTION Species______________________

1. a. __________Native __________ Planted__________ Grafted
   b. Clone/Cultivar name: _______________________________

Special Notes

2. a. Estimated age:________ years
   b. Circumference @ 4 ½ ft: ________ inches
   c. Estimated height: _________ feet
   d. Average crown spread: ___________ feet

3. Location (legal description, directions or town address)
   ____
   ____
   ____

4. Average interval between nut bearing: ______ year(s)

5. Estimated production: (husked nuts)

	#Nuts or	Bushels or	Pounds
This year	__________	_________	___________
Last Year	__________	_________	___________
2 Years Ago	__________	_________	___________

6. Have nuts from this tree been entered in past evaluations?
   Yes_____ No ______ What year ______ Entry #________

I enclose 15 nuts from above tree to be evaluated by the Nut Growers Association.

Return to: Nut Evaluation Committee

Name: ___________________________________

Address: _________________________________

__________________________Zip ___________

Phone: (_____)____________________________

NUT EVALUATION

The Nut Growers Association annually conducts a "Nut Evaluation Program" to locate nut trees which produce superior quality nuts. Common species for evaluation include: Black Walnut, Persian (English) Walnut, Pecan, Hickory, Butternut, Hazelnut, and Heartnut, but other tree entries will be accepted and evaluated.

Contest Rules

1. Each entry consists of 15 nuts (no limit on number of entries).
2. Nuts must be clean. Remove all husks (hulls); wash the nuts and allow to dry for about two weeks. A steel brush works well to remove residue.
3. A "Nut Evaluation Entry" form (or copy) must accompany each entry.
4. Entries should be received by December 31 or stored under refrigeration prior to the evaluation.

Please complete and return each entry form to: Nut Growers Association, Nut Evaluation Committee.

Name: ______________________ Address: ________________________________

Entry Number: __________ Code: __________

BLACK WALNUT EVALUATION SHEET

Native: __________ Seedling: __________ Clone: __________ Cultivar: ______________

Nut Quality

	Nut Quality	Grade
SEAL: Number of nuts: ______	#1 All Sealed tightly #2 1 or 2 defective nuts/5 nuts #3 2, 5 or more defective/5 nuts	__________
APPEARANCE:	#1 Uniform size, symmetric, smooth #2 Intermediate #3 Variable size, asymmetric, rough	__________
USEABILITY: ______Nuts out of__	#1 5 out of 5 nuts useable #2 5 out of 6 nuts useable #3 5 out of 6.5 or more nuts useable	__________
SIZE: Sample Weight _____grams	#1 > 20 gms./nut #2 15-19.9 gms./nut #3 < 14.9 gms./nut	__________

Cracking Quality

YIELD: Sample total Kernal wgt .______ total nut wgt.__________ x 100 = % kernel______

SEPARATION: Kernel recovered 1st crack = _________ gms. #1 > 90% 1st crack ______
Kernel recovered 2nd crack = _________ gms. #2 60-89% 1st crack
Total kernel recovered _________ gms. #3 < 59% 1st crack

PIECES: Kernels that are in ½'s =______ ¼'s = ______ #1 > 19/20 ¼'s ______
(½'s x 2 + ¼'s = No. of ¼'s) #2 12-18/20 ¼'s
#3 11/20 ¼'s

Kernel Quality

SIZE: Kernel wgt./nut = ______ gms. #1 > 5 gms./nut ______
#2 4.0-4.9 gms./nut
#3 < 3.9 gms./nut

COLOR: #1 Light & bright ______
#2 Intermediate
#3 Dark and dull

VEINS: #1 Slight ______
#2 Moderate
#3 Prominent

SHRIVEL: #1 > 19/20 ¼'s nonshriveled ______
#2 15-18/20 ¼'s
#3 < 14/20 ¼'s nonshrivelled

TASTE: Classed as #1 exceptional ______, #2 average______, #3 inferior______, ______

REMARKS: Total Grade ______

Final Score: ________

% Kernel
---------------- x 100
Total Grade

Placing: ______

*Forms for nut species can be obtained from the Iowa or Nebraska Nut Growers Association.

SCORING FORMULAS

1. MacDaniels Score*
   a. weight of a 10-nut sample in grams
   b. weight of kernels obtained by first crack
   c. total weight of all kernels in sample
   d. number of whole quarters of kernel in sample

The sample score is the sum of the weight of kernels from first crack in grams, the total weight of kernels divided by 2, and the number of quarters divided by 2. Pg. 436, Nut Tree Culture in North America.

2. Iowa Score No 1**
   Final Score = (crackout %) divided by (nut size + seal + appearance + useability + separation + pieces + kernel size + color + veins + shrivel grades) x 100

3. Iowa Score No 2
   Final Score = (crackout %) divided (nut size + seal + appearance + useability + seperation + pieces + kernel size + color + veins + shrivel grades) x 100

Iowa adds all three of the above scores together to get their final score.

*MacDaniels score favors large size nuts.
**Iowa Score No 1 favors the percentage of kernel in a nut.

4. Nebraska Score:
   Final Score = (crackout %) divided by (nut size + seal + appearance + useability + separation + pieces + kernel size + color + veins + shrivel + taste grades) x 100

BLACK WALNUT CULTIVARS

With greater than 35% kernel to shell ratios

Nebraska Evaluations 1987-1996

Source	Cultivar	Grams per Nut	Grams of Kernel/ nut	% Kernel	Nuts per pound	Lbs. Of Nuts per Lb kernal	Score	Rank
				1987				
Baker (MO)	Emma K	16.00	6.0	37.50	28.35	2.666	234	2
Bently (NE)	Krouse	12.80	4.6	35.94	35.44	2.783	200	4
				1988				
				No Cultivar scored over 35%				
				1989				
Bauman (OH)	Myers	15.60	5.66	36.28	29.08	2.756	259	1
Bauman (OH)	Emma K	18.00	6.70	37.22	25.20	2.686	248	2
Gardner (MO)	Emma K.	18.40	6.52	35.43	24.65	2.822	221	4
				1990				
UNL, M-7 (NE)	Sparks 147	17.15	6.07	35.39	26.45	2.825	236	3
				1991				
UNL L-9 (NE)	Sparks 147	17.20	6.64	38.58	26.37	2.590	276	1
UNL O-5(NE)	Wrights G-4	19.67	7.10	36.08	23.06	2.770	258	2
Lane (MO)	Jackson	13.38	4.85	36.29	33.90	2.759	242	6
UNL M-7(NE)	Sparks 147	13.43	5.06	37.67	33.77	2.654	222	9
				1992				
UNL P-7 (NE)	Sparks 127	12.00	4.46	37.26	37.80	2.691	233	3
				1993				
Lane (MO)	Sparks 127	17.34	6.19	35.68	26.16	2.801	223	2
UNL M-7 (NE)	Sparks 147	16.00	6.14	38.41	28.35	2.606	202	8
UNL L-3 (NE)	Sparks 127	11.55	4.11	35.58	39.27	2.810	19[illegible]	9
UNL L-1 (NE)	Sparks 127	11.40	4.26	37.36	39.79	2.610	197	10
UNL L-9 (NE)	Sparks 147	15.07	5.77	38.29	30.10	2.806	191	12
UNL O-5 (NE)	Wright's G-4	13.90	4.94	35.51	32.63	2.814	178	26
				1994				
UNL P-3 (NE)	Myers	16.06	5.62	35.00	28.24	2.858	233	2
UNL P-7 (NE)	Sparks 127	15.34	5.40	35.20	29.57	2.841	207	7

Source	Cultivar	Grams per Nut	Grams of Kernel/ Nut	% Kernel	Nuts per Lb.	Lbs. of Nuts per Lb. of Kernel	Score	Rank
1995								
Lane (MO)	Emma K	15.91	5.72	35.94	28.51	2.781	239	2
UNL L-9 (NE)	Sparks 147	14.19	5.06	35.65	31.97	2.804	178	16
1996								
Lane (MO)	Emma K	17.67	7.00	37.92	25.67	2.524	253	1
Lane (MO)	Sauber 1	13.74	4.84	35.19	33.01	2.839	207	5
L. Hay (MO)	Myers	13.88	5.28	38.01	32.68	2.629	165	23

BLACK WALNUT CULTIVARS
with greater than 35% kernel to shell ratios

Kansas and Missouri Evaluations 1984-1996

Source	Cultivar	Grams per nut	Kernel weight/nut	Percent Kernel	Nuts per lb.	Lbs of nuts per lb. Kernel
1984						
G. Gardner (MO)	Emma K	19.30	6.99	36.21	23.5	2.761
1985						
G. Gardner (MO)	Emma K	20.58	7.55	36.21	22.04	2.726
G. Gardner (MO)	Surprise	22.75	8.03	35.33	19.94	2.833
1986						
G. Gardner (MO)	Clermont	16.88	6.01	35.59	26.88	2.809
G. Gardner (MO)	Emma K	19.75	7.13	36.09	22.97	2.770
J. Williams (MO)	Emma K	15.54	5.58	35.89	29.20	2.785
1987						
J. Williams (MO)	Emma K	14.79	5.30	35.85	30.66	2.791
B. Lane (MO)	Sauber	15.76	5.69	36.08	28.79	2.700
J. Williams (MO)	Sparks 127	12.30	4.59	37.30	36.89	2.697
J. Williams (MO)	Bowser	14.03	5.01	35.70	32.34	2.800
P. Baker (MO)	Emma K	14.52	5.40	37.19	31.23	2.689
1988						
No cultivar scored over 35%						
1989						
R. Curtis (KS)	Emma K	14.97	5.58	37.25	30.31	2.681
B. Lane (MO)	Jackson	11.62	4.32	37.14	39.04	2.690

Source	Cultivar	Grams per Nut	Kernel Weight/Nut	Percent Kernel	Nuts per lb.	Lbs. of Nuts per lb. of Kernel
1990						
No Cultivar scored over 35%						
1991						
Ks. Exp. St. (KS)	Emma K	15.11	5.30	35.09	30.03	2.851
B. Lane (MO)	Jackson	13.09	4.73	36.16	34.66	2.767
1992						
J. Williams (MO)	Surprise	20.85	7.43	35.62	21.75	2.806
T. Blaufuss (KS)	Surprise	18.33	6.78	36.97	24.75	2.704
J. Williams (MO)	Emma K	16.18	5.78	35.72	28.03	2.799
T. Blaufuss (KS)	Emma K	14.84	5.32	35.83	30.56	2.784
J. Williams (MO)	S-127	12.56	4.81	38.32	36.10	2.611
1993						
Ks. Exp. St. (KS)	S-147	18.43	7.07	38.34	24.61	2.604
B. Lane (MO)	S-127	15.43	5.61	36.39	29.40	2.750
1994						
No cultivar scored over 35%						
1995						
B. Lane (MO)	Emma K	17.50	6.22	35.53	25.92	2.815
E. Provost	Surprise	16.89	5.97	35.37	26.86	2.829
Ks Exp. St. (KS)	Emma K.	17.74	6.62	37.31	25.57	
Ks Exp. St. (KS)	S-147	14.96	5.78	38.61	30.32	
1996						
Ks Exp. St. (KS)	DuBois 8201	17.92	6.35	35.42	25.31	2.822
Ks Exp. St. (KS)	Emma K	20.25	7.36	36.35	22.40	2.751
B. Lane (MO)	Sparks 147			37.63	33.31	
E. Williams (MO)	Emma K			35.48	30.21	

BLACK WALNUT CULTIVARS
With greater than 35% kernel to shell ratios

Kansas Evaluations 1959-1988

No. of Samples	Cultivar	% K. High	Nuts/Lb Low	Nuts/LB Mean
8	Emma K	36.56	21.34	26.93
7	Bowser	36.29	26.34	29.82
6	Clermont	35.59	24.70	34.00
4	Brown Nugget	35.50	27.10	29.07
2	Surprise	35.33	19.94	20.24
6	Myers	35.10	29.14	33.24

BLACK WALNUT–LATERALLY FRUITFUL CULTIVARS

By Cyril Bish
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Some eastern black walnut cultivars posses a characteristic known as lateral bud bearing. (Sparks, 1982) These cultivars produce pistillate flowers on a profusion of short, spur type branches distributed along main scaffold limbs. With this growth pattern, both leaves and nuts are born throughout the tree canopy resulting in increased yield potential. (Reid 1986)

To produce a black walnut cultivar for a commercial orchard, this characteristic is desirable and essential. In Persian walnuts, lateral bud bearing has resulted in significant yield increases. They also tend to be more precocious and are better suited to high-yielding and high-density plantings. (McGranahan, Leslie, Dandekar, Uratsu)

A cross breeding program needs to be done to develop a black walnut cultivar that will retain the lateral bud bearing characteristic. The resulting selection should also be anthracnose resistant, contain a kernel of at least six grams, crack out 40% kernel, and have a light colored kernel of excellent quality.

LATERALLY FRUITFUL BLACK WALNUT CULTIVARS

Cultivar Name	State	% Kernel	Grams/Nut	Anthrac-nose *	Reported By	Year reported resist.
Sparks 127	IA	37.4	17.3	MR	Archie Sparks	1982
Davidson	IA	28.0	21.5	R	"	1982
Crantz	OH	32.3	15.3	MR	"	1982
Beck	MI	31.5	13.6	R	"	1982
Pfister	NE	27.0	18.8	R	"	1982
Football	MO	30.0	19.6	MS	William Reid	1996
Emma K	IL	37.5	16.2	R	"	1996
Kwik-Krop	KS	31.0	17.4	MR	"	1996
Sparks 147	IA	38.0	18.4	MR	"	1996
Surprise	MO	34.0	19.9	MR	"	1996
Sauber	OH	33.0	16.9	R	Cyril Bish	1997
Vandersloot	PA	28.0	19.3	MR	"	1997
Hay #1	MO	32.0	19.2	R	Brian Sparks	

*R= Resistant, MR=Moderately Resistant, MS= Moderately Susceptible

LITERATURE CITED

Gale McGranahan, Chuck Leslie, Abhaya Dandekar, and Sandie Uratsu, Breeding and Genetic Engineering of English Walnut for Nut Production. Univ. of CA, Davis, 37.

Sparks, A. 1982. Lateral bearing black walnuts. Northern Nut Growers Association Annual Report. 73: 33-34.

Reid, W. 1996. Evaluation and management of black walnuts for nut production. Knowledge for the future of black walnut – USDA General Technical Report NC – 191, 211-216.

BLACK WALNUT ANTHRACNOSE REPORT

By Cyril Bish
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The eastern black walnut cultivars in the Cyril Bish Nut Tree Orchard, University of Nebraska – East Campus, Lincoln, Nebraska have been evaluated by Cyril Bish for Anthracnose resistance the past four years.

Tree leaves were observed to see if they showed evidence of the disease. Each tree was observed and given a rating as follows:

1. Resistant (R) Leaves healthy, and green to first killing frost.
2. Moderately resistant (MR) Leaves show a few spots on leaves. No leaf drop early.
3. Moderately susceptible (MS) Leaves show moderate amount of leaf spot. Some leaf drop early. Leaves yellow.
4. Susceptible (S) Most leaves show spots. Most leaves dropped early.

During the four year study there was a quite a variation in rainfall. This may have some affect on the amount of disease present during each year.

In 1994, we had 22.56 inches of rainfall which was below our normal of 28.26 inches.

In 1995, we had 23 inches of rainfall with a very wet May and June.

In 1996, we had 35.89 inches of rainfall. This was the 15th wettest year in 110 years or record keeping.

In 1997, we are about five inches below our normal rainfall with 21.84 inches reported as of November 2 and the normal for this date is 26.11 inches.

In 1995 only the top producing cultivars were rated for anthracnose.

It is important that black walnut retain healthy leaves the full season in order that the tree can produce a good crop of nuts each year. A late spring freeze can prevent pollination some years.

If a commercial orchard is to be established, it is important to plant cultivars that evaluate well and have good leaf health.

ANTHRACNOSE RESISTANCE
Black Walnuts – Lincoln, Nebraska

Location	Cultivar	Month, Day and Year of Observation			
		10/8/94	10/5/95	9/18/96	10/4/97
G-19	Pammel Park #20	MR		MS	MS
H-18	Wisconsin #1	S		S	S
I-18	Hare	MR		MS	MS
I-19	Lee Lowder	R		MS	MS
J-16	Vandersloot	R		MR	MR
J-17	George	R		MR	MR
J-18	Welch Rope	MS		MS	MR
K-9	Throp	MR		MR	R
K-10	S-127	MR	R	R	MR
K-11	Thatcher	MR	MR	MR	MR
K-22	Pamel Park #14	MR		S	MS
K-23	Pamel Park #20	MR		MS	
K-01	Sparks 328	R		R	R
K-02	Football 1	MS		MS	MR
K-03	Surprise	R		R	R
K-04	John Thordutti 1	R		R	R
K-05	Farm Thomas	R		MR	R
K-06	Sauber #1	R		R	R
K-07	M18	R		R	R
K-08	Burd	MR		MS	MS
KK14	Pammel Park #20	MR		MS	MS
KK15	Lee Lowder	MS		MS	MR
KK17	Mullinix	S		MS	MS
L-1	Sparks 127	R	R	R	MR
L-2	Farrington	MR	MR	MR	MR
L-3	Sparks 127	MR		R	MR
L-6	Krause	R	R	R	R
L-7	Burson	S		S	S
L-8	Stabler	MR	MR	MR	MR
L-9	S147	MR	MR	MR	MR
L-11	Ohio	R	R	R	R
L-12	George	R			MR
L-22	Pamel Park #14	MR		S	MS
L-05	Sparks MXS #4	R		R	R
L-06	Football	MR		MR	R
M-1	Sparrow	R	R	R	R
M-2	Hay	R	R	R	R
M-3	Ogden	R	R	MR	R
M-6	Davidson 629	R	R	R	R
M-7	Sparks 147	MR	MR	R	R
M-9	Crantz	MR	MR	MR	MR
M-9	Rock	MR	MR	MR	MR
M-10	Spilchal	MR		MR	MR
M-12	Thielenhaus	S		MS	MS
M-13	Davis #2	S			

Location	Cultivar	Month, Day and Year of Observation			
M-15	Bentley	S		MS	MR
M-02	Sparks 228	R		R	R
N-1	Beck	R		R	R
N-2	Hare	MR	R	MR	MR
N-3	Grundy	MS		MR	MR
N-4	Bowser	MR		R	R
N-5	Rowher	R	R	R	R
N-6	Kitty	MS		MS	MR
N-7	Caba Ohio	R		MR	R
N-8	Todd	R	R	MS	R
N-9	Leavenworth	R		R	R
N-10	Pfester #1	R		R	R
N-11	Bentley	MS		MS	MS
N-03	Scrimger	R		R	R
O-1	Sparks 328	R		R	R
O-2	Sparks 228	R		R	R
O-3	Pritchett	R		R	MR
O-5	Wrights	MR	R	R	R
O-6	Pritchett	R		R	R
O-23	Surprise	R			
P-2	Peanut	S	S	MS	MR
P-3	Meyers	R	R	R	R
P-6	Hare	R		R	R
P-7	Sparks 127	R	R	R	R
P-8	Cochrane	MS		S	MS
P-9	Kitty	MS		MS	MR
P-10	Crantz	MS	MS	S	MR
P-01	Tom Roe	R		R	MR
Q-4	Elkhorn	S		S	S
Q-5	Demming Purple	MS		R	MS
Q-6	Card	MR		R	MR
Q-7	Eldora	MR	MR	R	R
Q-8	McGinnis	R	R	R	R
Q-9	Sparks 128	MR		R	R
R-8	Thomas	MR	MR	MR	MR
R-10	Davidson 629	R		R	R
S-9	Sparks MS #2	R		MR	R

Propagating Eastern Black Walnut

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GROWER RECOMMENDATIONS

Use the best possible planting stock to establish a new black walnut orchard. Start with a vigorous rootstock grown from a known seed source. Chose black walnut cultivars with proven records of nut production for grafting onto your rootstock trees. Graft only well-established trees during the spring flush of growth. Select your propagation method based on the size of your stock tree. Use the 3-flap graft on small trees and the bark graft on larger trees. Support young grafts with a stake to prevent wind damage. Train the new graft to a central leader tree by trimming all growth to a single central leader.

INTRODUCTION

Black walnut trees will reach their full nut bearing potential only if careful consideration is given to the rootstock and cultivars used to establish the orchard. To ensure top quality orchard trees, many growers choose to grow their own rootstock trees and graft those trees with superior nut cultivars. In this chapter, black walnut propagation, from germinating seeds to grafting large trees will be discussed.

SEED PROPAGATION

Black walnut trees are easily grown from properly stratified nuts. Collect nuts for planting during the fall harvest season. Hull and wash the nuts as soon as you collect them. During the washing process, discard all nuts that float to the top (these floaters are poorly filled and won't germinate well). Even though many seed sources can be used, 'Kwik-Krop', 'Sparrow', and 'Thomas' nuts have proven to produce excellent rootstock trees. Stratify the nuts in moist sand by placing them in layers about 3 inches deep and holding them in a refrigerator (33 to 40° F) for 120 days. Be sure the nuts are kept moist throughout the stratification process to ensure uniform germination after planting. Three methods can be used for growing seedlings for later use in establishing a black walnut orchard:

1. Growing trees in place
2. Establishing a nursery
3. Growing trees in containers

GROWING TREES IN PLACE

Prepare a fine seedbed in the areas you intend to plant black walnut seed. During early spring,plant 3 to 5 stratified nuts, 2 to 3 inches deep, at each tree location. Be certain to mark the area where nuts are planted and to keep the area weed-free. During the first year, select the strongest-growing tree and remove the others by cutting them off below the root collar. Fertilize the seedlings in mid-

July with 1/4-cup of a slow release fertilizer per tree location. Water trees when conditions become dry.

ESTABLISHING TREES IN A NURSERY

Choose a deep, sandy loam soil for a black walnut nursery to facilitate digging and transplanting. Prepare a fine seed bed for the nursery area in early spring. Plant stratified seed 2 to 3 inches deep, 2 feet apart, in rows 4 feet apart. Keep the nursery weed-free and well watered. Sidedress the nursery rows with a slow release fertilizer in mid July. Nursery-grown trees should be dug for transplanting in March of the following year. When digging one-year-old seedlings, be sure to dig at least 16 to 18 inches deep and preserve as many fibrous roots as possible.

GROWING TREES IN CONTAINERS

There are several sizes and shapes of containers that can be used for growing black walnut seedlings. Choose a container with an open bottom. When placed on a screen wire bench, walnut roots will grow to the bottom of the pot and then become "air-pruned". The air-pruning process prevents root circling--a common problem in container grown trees.

Use a potting soil mixture that allows free movement of water through the pot. Mix in a slow release fertilizer that can provide both macro- and micronutrients for 7-9 months. Plant a single, stratified nut in each pot. Black walnut seedlings grown in containers need daily waterings and the careful attention demanded by all containerized nursery plants.

Container grown stock can be transplanted into the field in the early fall. The fall planting season starts 3-4 weeks before the first killing frost in the fall and continues until mid-November. Containerized stock can also be planted during the traditional spring planting season. However, if you are holding container trees over the winter, you must protect the trees from freezing during the winter. After trees become dormant in the fall, lay the pots down on the ground and cover the trees with an insulating cover.

GRAFTING TREES

The only way a walnut grower can ensure that each tree in his orchard produces quality nuts is to graft superior cultivars onto his rootstock trees. Trees grown from seed will, in most cases, bear nuts that are inferior to the nut planted. The seed grown tree exhibits characteristics from both male and female parents. Since walnut trees are wind pollinated, the source of male pollen is usually unknown. The pollen that fertilized the flower and resulted in the nut you plant may have come from a small, hard-shelled "wild" tree. As a consequence a seedling tree often produces nuts that are intermediate between that small, hard nut and the big nut that was planted.

Grafting is an age old horticultural technique that can be defined as attaching a twig from one tree to the stem of another in such a way that the twig continues to grow and become a permanent part of the tree. All of the branches that grow from that twig will have the identical characteristics of the tree from which the twig was taken. Grafting is one method nut growers can use to propagate trees that bear large, easily cracked nuts. Grafting a twig (the scionwood) from a tree that produces high quality nuts onto a seedling tree (the stock) is the only way to assure that your tree will produce desirable nuts.

COLLECTING SCIONWOOD.

The first step in the grafting process is to obtain scionwood from trees of known performance. There are hundreds of cultivars of black walnut that have been selected by nut growers over the last 100 years but only a few are frequently recommended for commercial nut production (see chapter on cultivar selection). Scionwood should be collected during the late dormant season. Cut scionwood from the previous season's new growth making sure there is an ample supply of large plump buds on the twig. Store scionwood in plastic bags under refrigeration (35° F) until the spring grafting season. Make sure the scionwood does not dry out during storage by wrapping the wood with moistened paper towels. Check stored scions frequently and rewet the paper towel if it become dry.

TOOLS FOR GRAFTING TREES

Before the grafting season begins you should collect all the tools and equipment you will need to graft walnut trees. The necessary supplies are listed below:

* Sharp grafting knife (sheep's foot blade)
* Pair of pruning shears (with by-pass blades)
* Pruning saw (turbo style)
* Light duty staple gun (Arrow model JT 21)
* Tack hammer
* 4-mil plastic grafting tape
* Plastic sandwich bags
* Aluminum foil
* Bottle of white glue
* 5/16" staples for staple gun
* 5/8" brad nails

With this equipment you will be prepared to graft trees from 1/2" to 4" in diameter.

SEASON FOR GRAFTING

During the spring flush of growth, rapid wood and bark growth allows the bark to be easily removed from the wood. We use this natural phenomenon to our advantage during the grafting process. But because the bark of the stock tree must 'slip', grafting season is largely confined to a six-week period during the spring. Graft small trees as soon as the emerging buds are one inch long. Start grafting larger trees when the leaves begin to unfurl. You can continue to graft until the leaves of the stock trees are completely expanded. During certain periods of the grafting season you will note excessive sap flow when black walnut stock trees are cut. This 'bleeding' will inhibit callous formation and cause graft failure. To avoid 'bleeding' problems, cut stock trees off just above the location you intend to graft. Wait a couple of days, and then make a fresh cut one-inch below your previous cut before grafting.

When you are ready to start grafting, take your scionwood out to the field in a small cooler. Ice down your scionwood to keep it fresh. Avoid leaving bags of scionwood out in the sun, where the wood can become very hot.

THE THREE-FLAP GRAFT

The three-flap graft is best method for propagating walnut cultivars onto stock trees three to six feet in height. The three-flap graft works best when both scion and stock are approximately the same diameter. Take a piece of scionwood out of your cooler and hold it up to the stock tree and choose the proper height for grafting (Fig. 1). Cut off the top of the stock tree at that point with hand shears. As a general rule, the scionwood should be large enough to allow you to cut off at least 1/3 of the stock tree.

After choosing the site for grafting, set your scion back in the cooler and prepare the stock. Begin preparing the stock by making three vertical incisions, three inches long, through the bark at the top of the stock. Space these evenly around the diameter of the stock. If a bud and leaf scar are present, rub off the bud and make the first vertical cut directly through the bud (Fig. 2). To facilitate tying the graft union during a later step, tie an 18-inch piece of plastic grafting tape on the stock just below the three vertical cuts.

Now turn your attention to preparing the scion. First, trim 1/2 inch off the bottom of the scion to fresh, green wood. With a sharp grafting knife, make a shallow cut through the bark and into the wood approximately 2 inches long at the bottom end of the scion (Fig. 3). This cut should expose a long "U" shaped area of cambial tissue with woody tissue inside the "U" (Fig. 4). Repeat this step two more times so that the scion has three evenly spaced cuts around its diameter. Leaving a strip of bark between each cut ensures maximum cambial exposure (Fig. 5).

Sometimes, a bud and leaf scar are found in a position where cuts are to be made. If so, make the first shallow cut so that it removes the bud. Before moving back to working on the stock, hold the cut end of the scion in your mouth (away from tongue and teeth) to keep the scion from drying and to free your hands.

Using the tip of your knife, separate the bark from the wood at the top of the stock. With your fingertips, carefully peel the bark away from the wood in three flaps, each 2.5 to 3 inches long. Use shears, blade side down, to hold the three flaps down while clipping out the wood on the inside of the flaps (Fig. 6). Avoid excessive fingering of the flaps--oily fingers can impair graft callus formation.

Next attach scion to stock. Place the scion inside the three flaps, lining up each cut surface with a flap. Hold the three flaps up over the cut surfaces with one hand and begin wrapping the graft union with grafting tape (already in place) (Fig. 7). Wrap the graft spirally up the stem, making certain the flaps and scion do not twist (Fig. 8). Tie the tape above the three flaps. Push straight down on the scion to ensure that the scion is firmly seated against the wood of the stock.

Protect the graft from sunburn by wrapping it with a small piece of aluminum foil (Fig. 9). Foil also acts as a splint, protecting the graft from wing injury. Next, tear the corner out of a plastic sandwich bag and place the bag over the graft (Fig. 10). Tie the bag above and below the graft union with grafting tape. The plastic bag helps prevent moisture loss and speeds graft callusing. Cover the cut surface at the top of the scion with a drop of white glue (Fig. 11), which prevents moisture loss from the scion.

Three to four weeks after grafting, scion buds should start to break (Fig. 12). After the scion has made three to five inches of new growth, carefully remove the plastic bag, aluminum foil, and grafting tape to prevent graft girdling. A strong graft should have callous tissue growing between each flap.

Wrap up the graft again in reverse order, first with the plastic bag, then aluminum foil, and finally grafting tape. This wrapping will not girdle the graft but provides wind protection. Force scion growth by pruning back growth below the graft and by fertilizing with nitrogen.

THE BARK GRAFT

The bark graft is an effective way to propagate walnut cultivars onto trees one to four inches in diameter. Select a point on the stock above the first whorl of branches and at a comfortable working height (Fig. 13). Retain lower branches to help maintain tree vigor until the new graft becomes established. Leaves on these branches will also shade the trunk to prevent sunscalding. Remove the top of the stock tree with your turbo saw. Check for excessive sap flow, and be prepared to graft another day if necessary.

Inspect the cut surface of the stock. You'll notice that the stem is not perfectly round. Choose the flat side of the tree to make your graft. At this point, remove some of the rough bark with your knife. Pare down the bark until it becomes about 1/8 in. thick in an area 1.5 in. wide and 3 in. long. Reducing bark thickness will make the bark more pliable and more able to conform to the scion. Use your grafting knife to make a 2.5-inch long vertical slit through the bark (Fig. 14). The stock is now ready to accept the scionwood.

Scionwood approximately 3/8 in. in diameter works best for the bark grafting. Trim 1/2 inch off the bottom of the scion with your pruning shears to expose fresh, green wood. If a bud is found near the base of the scion, your first cut should remove the bud (Fig. 15). Draw your knife through the scion starting about 2.5 inches from the base. Carve the scion down through the pith to less than half its original thickness using several passes of your knife (Fig. 16). This deep cut should be parallel to the scion and feature a right angle shoulder. Be certain that two buds remain above the cut.

Turning the scionwood piece over, make a shallow cut into the wood of the backside your first cut (this cut is similar to preparing a scion for three-flap grafting). This cut is not made parallel to the deep cut but angled to one side (Fig. 17). When finished, you should have a thin piece of bark adjacent to the deep cut on one side and a much thicker strip on the other. The cut on the backside of the scion should start just below the shoulder of the deep cut and should give the scionwood a wedge shape when completed (Fig. 18). A third cut is made perpendicular to the deep cut along the thick bark strip edge. This cut should be made just deep enough to expose the cambium. Be certain to leave a strip of bark between the backside cut and the perpendicular cut. At this point your scionwood should have a triangular shape (Fig. 19). Complete scionwood preparation by making a chisel point on the end of the bud stick (Fig. 20). This final cut should be made on backside of the scion.

Use your grafting knife to gently pull the stock's bark away from the wood on the right side of the bark slit (Fig. 21). Insert the scion between the bark and the wood of the stock (Fig. 22). Tap the scion down into the stock until the shoulder of the deep cut fits snugly against the upper side of the stock (Fig. 23). The deep cut should be facing the wood, while the shallow cut should be covered by the raised bark flap and perpendicular cut should fit snugly against the bark slit. Secure the graft union with staples (Fig. 24) or brad nails (Fig. 25). It is important to nail down the bark firmly against the scion and to be sure that all air pockets are removed. Use as many staples as needed but be careful not to split the bark.

Like the three-flap graft, cover the graft union with aluminum foil. Place the foil over the cut surface of the stock and around the base of the scion. Next, cut the corner out of a sandwich bag and place over the scion. Tie the plastic bag with grafting tape to the base of the scion and bellow the aluminum foil on the stock (Fig. 26). Place a drop of white glue on the cut surface at the top of the scion to prevent moisture loss.

When you see about six inches of new growth from the scion, attach a piece of lath wood (1/2 x 1 inch) to the tree to prevent the wind from blowing out the graft. Nail the lath to the stock and tie the new shoot to the lath with twine or plastic grafting tape. The young graft will need support until new wood grows over the cut surface on the stock (two or more years).

GRAFT AFTER CARE

One year after grafting, prune the growth on the graft to a central leader. If more than one bud grows from the bud stick, leave only the growth coming from the strongest bud to form the new top of the tree. During this same time, prune off about one third of the lower limbs to force more of the trees energy to the graft. In subsequent years, continue pruning the top of the tree to a central leader and remove limbs below the graft.

Project Planning, Design and Planting

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In order to develop an economic viable enterprise producing Black Walnuts one needs to consider basic criteria that will effect the overall success or failure of the enterprise. We should consider a relatively long period of time i.e. 35 to 50 years or longer. This can be quiet a challenge in an era where as producers we much constantly be market responsive and subject to change.

In planning an orchard that hopefully will encompass efficient, quality production we should first look at four basic points and build an outline from these points with as much input form everyone as possible.

Point I - Produce the crop, harvest it, process it
Point II - Market It
Point III - Deliver it
Point IV - Collect your money

I. PRODUCING THE CROP

A. Orchard site selection
   1. Identify soil
   2. Soil amendments
      a. Should be based on soil tests showing the nutrient status.
      b. Necessary amendments should be made prior to tree planting.

B. Variety selection
   1. Genetic improvement
      a. A decision should be made where primary emphasis is to be focused, nut production only or a combination of nut and timber. It is my personal belief that in theory it sounds possible to do both, but management practices dictating maximum yields, efficient harvesting, (both dependant on proper spacing,) crown development, and branching structure for shaking, make this impractical. This is not to say that the exceptional individual who is willing to accept the challenge cannot do both but this will be the exception and not the rule.
   2. What does the market want
   3. Regional adaptability
   4. Precocious selections
   5. Planting stock
      a. Understock should be selected and grown from known parentage proven to be superior in root development and growing vigor. A one year stock will respond best and should be about 3/8 inch – ½ inch in caliper. Younger understock has definite advantages provided

desired size can be attained, whether being planted bare-foot or containerized. Planting of containerized understocks or grafted varieties in containers can be done either in the spring or fall. Fall has several advantages over spring. Soil and weather conditions nearly always allow favorable planting conditions. Roots will grow at soil temperatures at 50 degrees or above so establishment will begin immediately allowing the tree to be in a better condition to withstand usual spring competition and summer drought. Ideal fall planting time for containerized walnuts in Missouri would be from October 20^{th} to Thanksgiving. (Soil temperatures will remain above 50 degrees into Dec.) Fall planting alone can result in a one year gain in establishment and growth.

Bare-root walnuts are planted spring only to avoid winter desiccation and heaving problems from alternate freezing and thawing. Very early spring planting will give best results, however spring conditions often delay plantings so severe weed competition, and moisture competition often occur at a critical time period when the plants are trying to become established.

C. Orchard design

1. Nut production only or timber combination: (Is this feasible)

a. The primary goal should be production of high volumes of high-quality nuts, in both yield and color. The market will pay a higher price and the bottom line will improve. Net return per acre is of primary importance.

Optimum crown development:

(1) Spacing to accommodate crop production will vary to some extent by the cultivar, pruning methods, thinning and other management factors. Optimum bearing potential is realized when the space over the soil is completely occupied by nut-bearing tree canopies with sufficient light penetration to maintain lower fruiting wood. A practical median spacing based on the above criteria would be 30 x 30 requiring forty-eight trees per acre.

Walnut breeding and generic improvement will likely develop dwarf cultivars that should be planted at closer spacings or possibly in hedge rows. Here are some sample spacings showing number of trees required per acre.

20 x 20	109
20 x 24	90
22 x 22	90
24 x 24	75
25 x 25	69
30 x 30	48
40 x 40	27
50 x 50	18

(2) Facilitate efficient harvesting and handling of crop.

2. Pollenizer Trees
   a. Use of pollenzier varieties may be desirable in many walnut orchards. It is essential to place these trees correctly for maximum benefit. Since walnuts are wind pollinated the pollenizer trees should be planted in solid rows perpendicular to the direction of prevailing winds at regular intervals. They should be planted in solid rows so they can be harvested separately.

D. Husbandry
   1. Pruning - Do you desire a single straight log or a broad crown that will produce more nuts?
   2. Early life of orchard requires checking each tree several times each growing season for all essentials to provide maximum health of trees.
   3. Always be aware of the Five essentials for plant growth: Light, Temperature, Water, Air, Nutrients:
   4. Competition
      a. Weed control
      b. Spacing
   5. Disease and Pest Control

      (What is pre-harvest cost per acre to establish? $1,000 - $1500.00/per acre using cultivars.)

      (Goal should be to produce 1,000#/per acre as quickly as possible to approach profitability with an ultimate goal to produce twice this amount per acre in 5-7 years.)

II. MARKETING

A. Specialty markets and outlets
   1. Must yield prices that will support and provide return on orchard investments:

B. Keep cultivar selection in line with market demands:
   1. Market changes may require top working to new and better cultivars.

C. Continually be aware of market changes, wants, and needs:

D. Collectively or individually we need to target specific markets then make personal contacts, promote through advertising and make use of new technologies as the internet to market our product:

E. Good packaging and point of sale merchandising.

III. DELIVER

A. Gain a reputation as a consistent dependable supplier of quality product:
   1. This may necessitate storage and other ways to have the product available on a year round basis:
      a. Seed with a moisture content of 20 to 40 percent can be stored at 34° – 37° F for one year.

B. Certainly in season customers may be encouraged to come to you direct:
   1. Farmers markets may be viable outlets in certain instances.

IV. COLLECT YOUR MONEY

A. No sale is complete until you are paid:

1. If shipping on credit have firm understanding of terms of sale:
2. By producing a quality product, with innovative marketing and techniques, and on time delivery, collecting your money is made much easier.

Landowner Assistance Through State and Federal Programs

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GROWER RECOMMENDATIONS

Contact your local natural resource government agency. They can help you formulate a management plan, and will have suggestions about which government programs are available to help you accomplish your goals.

Knowing your soils is a key to being successful with your trees. Each county has a Natural Resources Conservation Service (NRCS) office to serve the needs of that county, and soils is one of their areas of expertise. They will have soils information about your property, and will be able to interpret which soils are best suited for your purposes. This will help in the decision of where to plant, and what kind of growth you can expect.

The local Missouri Department of Conservation (MDC) forester can provide a list of contractors to assist with planting, pruning, or removing trees. Similar agencies in other states should be able to provide the same service.

There are a wide variety of government programs that could be used to establish and maintain your trees. Which program to utilize will depend on individual situations, but this brief description of the programs currently available should help in deciding which option you should pursue.

The Conservation Reserve Program (CRP) contains options for planting trees. This program is administered through the Farm Services Agency (FSA). The Forest Incentive Program (FIP) was designed to improve the productivity of the forest resource. Because the program is focused on productivity, the land enrolled in this program must meet a minimum productivity rate of 50 cubic feet of wood per acre per year. This rate is determined by soil type. FIP can be used to establish trees, and to maintain or improve trees. The program is administered through the NRCS.

The Stewardship Incentive Program (SIP) is the cost-share companion to the Forest Stewardship Program, which helps a landowner achieve their goals for their property. Establishing and improving trees is a component of this program that is administered through both the FSA and the MDC.

The Soil and Water Conservation Program is commonly called State Cost-Share. The DFR-4 part of the program has the goal of establishing trees on land previously used for agriculture. Because it is administered through local Soil and Water Conservation Districts (SWCD), the availability of this program can vary from county to county.

The Missouri Agroforestry Program was created to promote the use of trees with other crops". Walnut plantings are commonly used in agroforestry in conjunction with grains, grass, cattle, berries, and even medicinal plants. The program is administered by the MDC.

The Wildlife Habitat Improvement Program (WHIP) is a cost-share program designed to improve wildlife habitat on private lands. Tree planting and timber stand improvement are eligible practices. NRCS administers the program.

The Environmental Quality Incentive Program (EQIP) is designed to address soil, water and related natural resource concerns on private lands. Cost-share practices can include tree planting if specified in the state or local priority area plan. NRCS has technical responsibility for the program.

Whether or not you use any of these programs, the agencies mentioned are available for providing free technical assistance, and an on-site visit if necessary. You, the landowner, are the key to good conservation and the future of our natural resources, and government agencies really are "here to help you" - use them.

PART 3

THE EASTERN BLACK WALNUT TREE AND FRUIT

Carbohydrate Assimilation, Translocation, and Utilization

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GROWER RECOMMENDATIONS

Tree growth and nut production are primarily a function of carbohydrates made available through photosynthesis. Photosynthesis occurs mainly in the leaves and is control by the amount of light, carbon dioxide, and water available to the leaves.

Photosynthesis in walnut increases proportionally to the amount of light reaching the leaves up to one-third of full sunlight. Nut production requires use of thinning and pruning practices that develop trees with large crowns with leaves exposed to light of moderate levels of sunlight for at least part of the day. Pruning is especially important on lateral bearing cultivars to allow light penetration to the fruiting spurs. Carbon dioxide, an essential ingredient for production of photosynthates, enters the leaves primarily through the stomata. Insufficient soil moisture during summer droughts results in reduced transpiration and closure of stomata. Excessive soil moisture can lead to unhealthy roots incapable of supplying sufficient water to the leaves for transpiration. Photosynthesis and respiration are biological processes that involve plant proteins or enzymes made up of carbon, nitrogen, oxygen, and various mineral nutrients. Different parts of a walnut tree have changing demands during the year for photosynthates for respiration, growth of new plant parts, and the developing nut crop. Depending on the cultivar, heavy crop loads may adversely affect the following year's crop by adversely affecting female flower initiation and reduced amounts of stored carbohydrates. Anthracnose, a common leaf spotting disease, utilizes carbohydrates that normally would be used by the tree for growth and nut production. Late summer fertilization in Missouri may enhance nut production by reducing severity of anthracnose or possibly altering the plant growth regulators involved in female flower initiation and development. The processes associated with nut production appear to be under strong genetic control; thus annual heavy nut production will require selection of walnut cultivars exhibiting multiple leaf layers to maximize photosynthate production, tendencies toward lateral bearing, good resistance to anthracnose, and efficient use of photosynthates for tree growth and nut production.

TECHNICAL INFORMATION SUPPORTING RECOMMENDATIONS

Many environmental factors and cultural practices can affect the ability of walnut trees to convert atmospheric carbon dioxide (CO2) via leaf photosynthesis into carbohydrates, the subsequent translocation or distribute these carbohydrates throughout the tree, and, finally, their utilization for respiration, growth, or nut production. Little research has been done on carbohydrate assimilation, translocation, and utilization in eastern black walnut; however, what we know about these processes appears similar to what has been found for other walnut and large mast producing species. Thus, when information was not available, research information obtained by other researchers was used on carbohydrate assimilation, translocation, and utilization within English walnut (Juglans regia L.) and pecan to develop the following picture for eastern black walnut. Figure 1 is a schematic representation of the carbon cycle for eastern black walnut as adapted from the model for English walnut developed by DeJong and Ryugo (1985).

The carbon cycle begins with the conversion of carbon dioxide and water into carbohydrates CH ^{2} 2O)n and oxygen through a process called photosynthesis. Green pigments (chlorophylls) capture light energy from the sun and convert it into chemical energy. This chemical energy is used to drive the reduction of carbon dioxide into simple carbohydrates that eventually become sugars. The actual process consists of a complex series of chemical reactions. As depicted in Figure 1, the leaves take up carbon dioxide and produce sugars that become part of the photosynthate pool. Depending on the demands for energy within the plant, these photosynthates can be translocated to other plant parts or converted to starches and stored for future use. The sugars are broken down to produce the energy (growth respiration) needed to assimilate other sugar-derived chemicals into various cellular components or broken down to produce the energy needed to maintain living tissues (maintenance respiration).

The carbon dioxide used during photosynthesis comes from the air surrounding the leaves primarily through stomata located on the lower surface of the leaves. The size of the stomatal opening is regulated by two guard cells that are quite sensitive to various environmental factors. These stomatal openings are also important in controlling the transpiration rate or loss of water vapor from the leaves. If insufficient water is available to the leaves, the stomata close and cut off the supply of carbon dioxide needed for photosynthesis to occur.

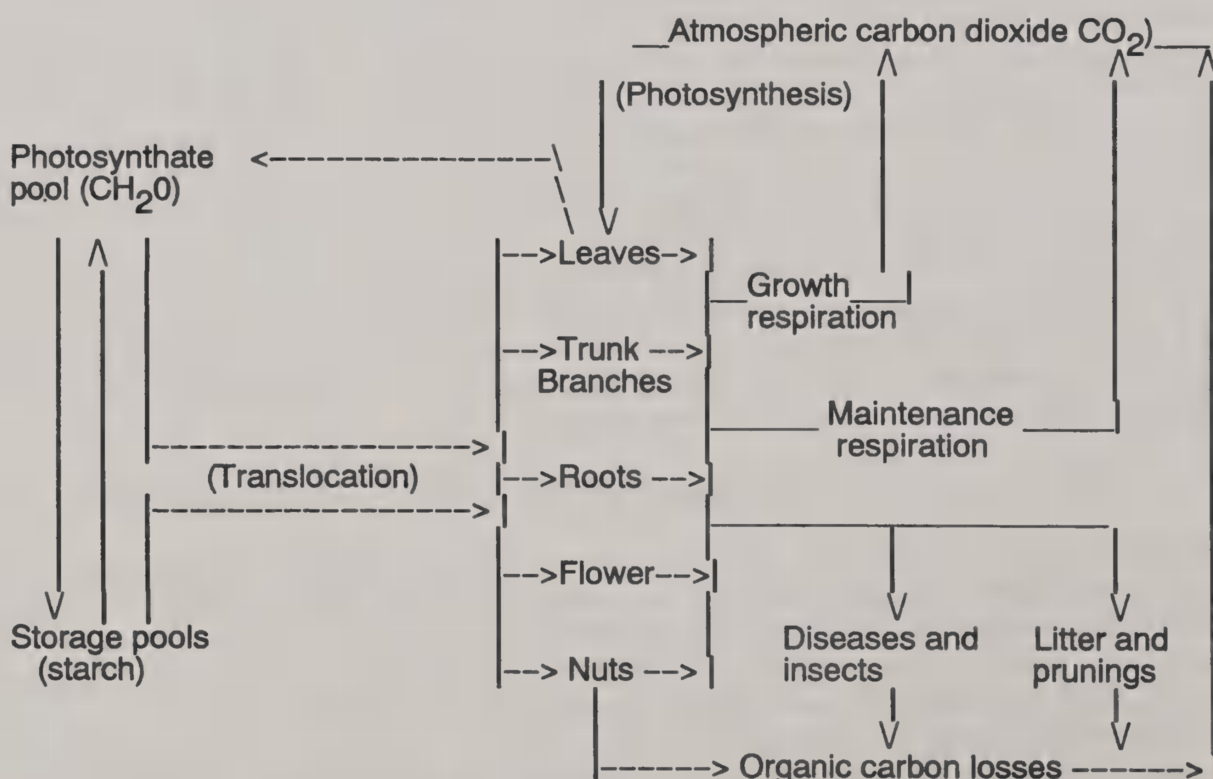

Figure 1. Carbon cycle for nut-producing eastern black walnut trees.

FACTORS INFLUENCING PHOTOSYNTHESIS, PHOTOSYNTHATE POOLS, AND RESPIRATION

Light intensity - Walnut leaves produce photosynthates proportional to the amount of sunlight striking the leaf surface. Their leaves can effectively utilize up to approximately one-third of full sunlight after which increases in light do not result in additional production of photosynthates. The same photosynthetic mechanisms are activated at light intensities of five percent of full sunlight. Eastern black walnut has relatively thin crowns, so most leaves are likely to be exposed to light levels within this range for at least part of the day as the sun moves across the sky. If walnut trees are not thinned or the canopies are allowed to become to dense, the inner portions of the tree crowns become so shaded the leaves cannot produce sufficient photosynthates for maintenance respiration and die. This is especially important in high-production nut orchards using cultivars with lateral bearing characteristics. These cultivars have leafy fruiting spurs on the inside of the tree crown along the main branches. On English walnut, if the leaves on these spurs receive insufficient sunlight, the spurs eventually die. It is unclear if lateral bearing cultivars of eastern black walnut will also produce crowns sufficiently dense to lead to death of fruiting spurs.

Temperature - Most plant processes, including photosynthesis and respiration, have a minimum temperature at which the process begins and an optimum temperature for maximum efficiency. Above this temperature, the processes slow until lethal temperatures are reached. For English walnut, photosynthesis has a broad optimum between 60 and 86 °F after which the rate of photosynthesis rapidly declines. High temperatures are also very likely to limit the rate of photosynthesis in eastern black walnut, especially when the stomata are closed in response to limited soil moisture. Photosynthesis and respiration probably show similar response patterns to increasing temperature, although optimum temperatures for respiration are probably higher than for photosynthesis.

Deficient water supply - Insufficient available soil moisture causes stresses that can lead to wilting and premature defoliation under extreme conditions. Under less extreme conditions, the stomata close to decrease the rate of transpiration. When this occurs, carbon dioxide can no longer enter into the leaves through the stomata and photosynthesis decreases. If nut orchards are not going to be irrigated, then soil depth and water holding capacity become very important during site selection for the nut orchard. The water held within the rooting zone determines if adequate soil moisture is available during dry spells. In the Central Hardwood region, droughts usually occur in late summer when there is a high demand for photosynthates to fill the developing nuts. Lack of adequate soil moisture in late summer can also affect the physiological condition of the tree and suppress the initiation of female flowers necessary for the following year's crop.

Excess water supply - On soils subject to flooding or with shallow restrictive layers, excess soil moisture can also be a problem. Excess soil moisture during the growing season leads to decreased oxygen in the soil and death of roots needed to absorb adequate soil water during periods of high transpiration. On soils with restrictive layers in the walnut rooting zone, soil water accumulates above the restrictive layer leading to a perched water table during the dormant season. Walnut roots within the perched water table die from a lack of oxygen. If these roots are not replaced during the growing season, it results in a reduced capacity to absorb soil moisture during the following growing season followed by stomatal closure from moisture stress and subsequent decreases in the rate of photosynthesis.

Nutrient supply - Maintaining proper mineral nutrition will be important for maintaining high rates of photosynthesis. Plant nutrients play important roles in the mechanisms for light trapping and in the carbon conversions associated with photosynthesis. Nitrogen is an important component of the amino acids that make up the proteins or enzymes involved in both processes. Phosphorus is an essential element in the chemical processes associated with energy transfer. Elements like potassium, magnesium, manganese, and iron are important cofactors associated with the proteins or enzymes involved with photosynthesis. Other elements like boron are important for nut production in English walnut. Research has shown that late summer application of nitrogen in black walnut plantings will enhance nut production.

Carbon dioxide concentration - Although atmospheric changes in carbon dioxide within walnut canopies can range from 350 to 600 ppm, these amounts are still adequate to maintain high photosynthetic rates. In fact, high carbon dioxide concentrations have been shown to increase the growth of eastern black walnut seedlings. However, stomatal closure in response to high temperatures or insufficient soil water will lead to low carbon dioxide concentrations within leaves and reduced rates of photosynthesis.

Insects and diseases - Anthracnose, a common leaf spotting disease, can cause significant losses in photosynthates during disease development and premature defoliation of trees. Initial infections occur in the spring and increase rapidly during wet weather. Significant amounts of photosynthates are drawn to the developing infection centers before they become visible. Heavy infection usually leads to premature defoliation during the period of female flower initiation and kernel maturation. Some walnut cultivars show good resistance to the leaf spotting disease. Cultural practices that decrease overwintering spore populations or increase nitrogen availability during the growing season have also been shown to be effective. Insects that feed on foliage reduce the leaf area and can affect the supply of photosynthates to the tree for growth and nut production.

TRANSLOCATION AND UTILIZATION OF PHOTOSYNTHATES

The goal of orchard management is to maximize photosynthesis and partitioning of photosynthates into a harvestable nut crop with minimal losses to pests, disease, or excessive growth. Virtually anything that is done to manage the orchard will influence some aspect of the carbon economy. The translocation of carbohydrates from the photosynthate pool can be viewed as a series of conflicting demands made on a limited resource (Van Sambeek and Rink 1982).

Although leaves are normally thought of as a source of photosynthate it is important to recognize that they are important sinks for photosynthates during their initiation and development in the spring. The primary sources of photosynthates at this time are stored reserves or starch in the bark and roots. Late spring killing frosts are especially damaging because the walnut tree must initiate a second set of shoots from already depleted storage reserves. It is not until leaves attain about half their maximum size that the sink-source relationships are such that a leaf produces sufficient photosynthate to complete its development. When leaves reach two-thirds of their maximum size, they become net exporters of photosynthates.

In addition to leaf initiation and elongation, stored starch is also necessary for shoot elongation and development of male catkins and pistillate flowers. Flowers begin to appear about mid April in the south and progressively later until early June in the northern parts of the natural range of eastern black walnut. If the walnut trees produced a heavy crop of nuts the previous year, these starch reserves may only be adequate to develop weak pollen and pistillate flowers. When leaves initiated during bud burst reach full size, they become important sources of photosynthate for the developing nuts, additional shoot elongation, and initiation of next year's male catkins. A developing nut crop is a stronger sink for photosynthates than these other processes and can limit additional shoot and leaf initiation and elongation.

During May and June, the fertilized nuts go through a period of rapid expansion. At the same time, the trees are putting on rapid height and diameter growth. During July, photosynthate demands remain high as nuts go through a period of nut expansion and shell hardening for the next month. Summer droughts during these three months will reduce photosynthesis and availability of photosynthates to the developing nuts resulting in small nuts.

In August, the embryo grows into the nut cavity and absorbs the endosperm. During September, fats are deposited as the kernel develops and matures. This is also the period when walnut forms pistillate flower initials in the terminal buds. Because photosynthate sinks closest to the leaves tend to be the strongest, foliar leaf diseases like anthracnose can utilize a significant amount of the photosynthate produced. Insufficient photosynthates in the late summer and fall can result in shriveled kernels and development of weak pistillate flowers. Once the nuts are mature and until the leaves are lost to disease or a killing frost, photosynthates are translocated to storage tissues for utilization the following spring. The mature nuts usually drop a few days after the leaves fall in October.

Recent studies in southern Missouri have shown mid-August fertilization with chemical weed control can significantly enhance nut production the following year. Because late summer fertilization can delay dormancy, recommendations still need to be developed for the timing of fertilization in the northern part of the walnut range to prevent winter damage. Several explanations have been suggested as to why later summer fertilization increases nut production. Increased nitrogen within the branch tips may alter the plant growth regulators responsible for the fall initiation of female flowers with the dormant buds. It may be the added nitrogen suppresses foliar diseases so that leaves are retained for a longer period and increase the stored reserves. It is generally recognized that increasing the length of leaf retention following nut maturation will decrease the alternate bearing tendency. The choice of ground covers can also greatly influence the retention of leaves into the fall and the amount of stored reserves that are deposited in the bark and roots.

Some studies suggest photosynthetic efficiency, translocation, and nut production appears to be under strong genetic control. In one study, Hammons Products Company determined the individual tree production on more than 12,000 trees during a seven-year period. During this time, around 40 trees produced no nuts while three trees produced more than 300 pounds of nuts annually. In general the heavy bearing trees are not significantly smaller than adjacent trees that have produced few nuts. The heavy bearing trees have lateral bearing characteristics with numerous fruiting spurs. These spurs normally produce eight to ten leaves which may dramatically increase the total leaf area and the amount of photosynthates needed for high nut production.

LITERATURE CITED

DeJong, Theodore M. and Kay Ryugo. 1985. Carbohydrate assimilation, translocation, and utilization. Pp. 64-68. IN: Ramos, David E., ed., Walnut Orchard Management, Cooperative Extension, Division of Agriculture and Natural Resources, University of California.

Funk, David T. 1979. Black walnuts for nuts and timber. Pp. 51-73. IN: Jaynes, Richard A., ed., Nut Tree Culture in North America. The Northern Nut Growers Association, Inc.

Van Sambeek, J.W. and George Rink. 1982. Physiology and silviculture of black walnut for combined timber and nut production. Pp. 47-52. In: Black walnut for the future. USDA Forest Service Gen. Tech. Rep. NC-74.

Floral Biology And Pollination Of Eastern Black Walnut

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GROWER'S RECOMMENDATION

Controlled pollination in black walnut is primarily used to supply nuts for breeding purposes, not for the mass production of nuts for food or reforestation. While not absolutely foolproof, controlled pollination ensure that both parents of the progeny are known. With open pollination (pollen spread through the air by the wind), only the mother tree on which the nut is found is known. Nut yields per pollination bag are not very high; the average yield is usually less than one. Of course, this value depends on how many flowers are initially in the bag. Open pollinated flowers, also, have poor survival after pollination. Linit and Necibi (1995) found that only 30 percent of walnut flowers matured into nuts under open pollinated conditions of agroforestry.

The following paragraphs give a brief description for how to make a controlled pollination. This is not meant to be the last word in learning the technique, but rather an attempt to arouse your curiosity and start you thinking about making a cross of your own. Ok, how do you make a controlled pollination?

- The first step is to select the trees that you will us as female and male parents.
- Identify the pistillate flowers (females) and the staminate flowers (pollen catkins) before the pollen starts to shed. Controlled pollination is not reliable once pollen is in the air.
- Place a pollination bag over the female flowers while the pollen catkins are still green, making sure to remove any catkins on last year's branch that may accidentally be enclosed in the bag. You don't want to contaminate the flowers with selfed pollen. Pollination bags with clear plastic windows can be purchased at supply houses. Wrap the branch with "polyfill" where the mouth of the bag will make contact. This will provide a good barrier to prevent stray pollen from entering the bag. Wrap the bag and polyfill tightly to the branch with a "pulltight" to prevent the bag from moving or opening.
- Collect pollen catkins from the desired make tree when they are "plump" and yellow, but before they begin to shed their pollen. Put all the catkins into a brown paper (lunch) bag and close the bag to prevent pollen from leaving. Make sure that you write the tree's identity on the bag.
- Let the catkins dry in a warm location for a day or two, so that the pollen is released when the closed bag is gently tapped. Make sure other bags containing catkins are kept closed when you open the bag. Open the bag SLOWLY and gently pour the contents of the bag into a small-hole screen sieve that is setting on a clean sheet of white paper. The pollen will pass through the screen and most of the catkin material will remain. Pour the pollen into a small glass vial and cover. Attach a #22 disposable needle to a disposable hypodermic syringe that is labeled with the pollen source. Then pull the plunger from the syringe and pour some pollen into the barrel. Carefully insert the plunger into the barrel so that is sealed. Store temporarily in a cool place so that the pollen doesn't overheat. After each bag is processed, wipe the area that you are working

in with a 70 percent ethyl alcohol solution to kill the residual pollen. Do this step inside where there are no drafts.

- Examine the female flowers through the window in the bag. When the stigmas of the flowers are expanded, pinkish in color, and appear moist, it is time to apply the pollen into the bag. Insert the needle of the syringe into the bag and squirt pollen toward the each flower. It doesn't take much pollen to make an effective pollination. Remove the needle from the bag and put a piece of tape across the hole. The tape has to be resistant to moisture so it doesn't fall off. Write the pollen source on the bag so that you know the identity of the male parent.
- In several days, examine the female flowers on the trees to see if they are no longer receptive. The stigmas should be dry and starting to turn brown. At that point you can remove the pollination bags. Cut the pulltight with wire cutters, gently open the mouth of the bag, and remove the bag and polyfill. Count the number of female flowers that were in the bag and put it in your record book. Place an aluminum identity tag on the branch where the polyfill was located. You will know that any nuts beyond the tag were the result of your pollination. This tag, see below for example, should have the female tree number (9825), the number of that specific branch (01), and the identity of the male parent (8686). When the surviving nuts are removed from the tree, the tag should accompany them; it is their identity and lineage.

9825-01 x 8686

The formulation of a cultural program for eastern black walnut (Juglans nigra L.) that does not primarily depend upon information gathered from the English walnut (J. regia L.) industry in California is a slowly evolving process. This is not to say that the scientific and institutional wisdom from that industry is not valid, it just may not always be applicable. Members of that California industry have made large investments of resources to attain and fine-tune that wisdom; we have not yet arrived at that point of making large investments or of accumulating as much wisdom. To that end, this paper will comment on our state of knowledge concerning flowering biology and pollination of black walnut. Accurate information is necessary if we are to consistently produce and manage a flower crop and bring it to maturity as a nut crop. Readers are referred to a previous paper on this topic to assess where we have been (Cecich 1989). The objective of this paper is to discuss how far we have come in the last 10 years and how far we have yet to go. Definitions of some terminology are provided at the end of this chapter.

A REVIEW OF EASTERN BLACK WALNUT FLOWERING

We see flowers only as they emerge from the bud and get pollinated; then we see the fruits as they develop and eventually mature. However, flowering is a very complex process and most of it occurs at the microscopic level. Table 1, an outline of a typical classification scheme for studying flowering biology, demonstrates this complexity. There are three major components to the flowering process in walnut: 1) Initiation of primordia, 2) Differentiation or development of the staminate and pistillate inflorescences and their flower primordia, and 3) Emergence of the flowers, followed by receptivity of the stigmas and shedding of pollen.

Initiation

Initiation refers to the process by which chemical, genetic, and abiotic factors interact during a critical time period to cause a meristem, or a cell within it, to commit itself to become a flower or flower part. This is not the same as differentiation wherein the structural manifestation of the initiation process occurs; e.g., the appearance and development of an inflorescence. Most of what we know about flower initiation is based on research with annual plants (Bernier 1988, Bowman et al. 1989, Shannon and Ry Meeks-Wagner 1990, Smyth et al. 1990). However, woody plants behave differently than annuals. They have long juvenile periods during which they don't flower, even though the proper environmental stimuli may be present. Because woody plants must grow year after year and maintain a certain crown structure, their flowers are normally in an auxiliary position, not terminal as they usually are in annuals.

Differentiation

Differentiation of reproductive structures extends from the time of inflorescence initiation in a bud (possibly early summer in black walnut) to the time of pollen shed for staminate flowers and post-emergence for pistillate flowers about one year later. This time period does not include the events following fertilization of the ovule; that period is allocated to fruit or nut development. During that year, discrete stages of flower development can be observed with a microscope, most occurring in the last 2-3 months before flower emergence. Environmental factors such as ice storms, insects, and drought can have an impact on differentiation of plant tissues. So we ask: Can the success or failure of flower development during that year be attributed to these factors? Except for deep freezes in late spring that kill the swelling buds or foliage, there is no definitive proof that weather affects differentiation of the flowers. When pistillate flower production of a good producer is low in any given spring, was flower differentiation in that tree disrupted by genetic, physiological, or environmental factors during critical times; or were the pistillate flower primordia ever initiated? There is not likely to be one simple answer to this question. Linit and Necibi (1995) determined that about 30 percent of the pistillate flowers on J. nigra grown under agroforestry conditions matured into nuts. However, of the 70 percent of the flowers that aborted, curculio weevils (Conetrachelus retentus (Say)) were estimated to account for 8-17 percent of the total flowers. The largest component of flower loss (about 50 percent) occurs before the loss related to curculios.

Genetic control over nut production (not flower production) in walnut has been demonstrated by a number of investigators (Funk 1970). Fecundity can be increased by selecting high-yielding clones and putting them into a grafted orchard (Farmer 1981). However, in a given year, seed production among clones may vary according to the percentage of pistillate flowers that were fertilized; while year-to-year differences may be associated with the number of flowers available for pollination. You can not simply select for nut production, because nut production depends on the number of flowers that survive. Selection must also take into account flower production -- male and female. The best nut-producing selection in the world is no good if there is no pollen to complete the journey from the pistillate flower to the nut.

Perfect flowers, those in which the male (staminate) and female (pistillate) flower parts exist within the integrity of a single flower, do not occur in walnut. Walnut trees are wind-pollinated and classified as monoecious; male and female flowers are on the same tree, but separated from each other. However, the male flowers on a given tree do not normally shed pollen when the female flowers on that tree are receptive. This condition is called dichogamy. If the male flowers shed their pollen before the females are receptive, that type of dichogamy is known as protandry. If the pollen is shed after the female is receptive, it is classified as protogyny. It is believed that dichogamy has evolved to reduce or prevent inbreeding or self-pollination in a tree. Therefore, to increase the probability of cross-pollination, plantings should include cultivars or selections in which pollen shed and female receptivity occur at the same time. This alignment can be independent of whether one uses protandrous or protogynous selections of black walnut.

Emergence, Receptivity, and Shedding

Emergence of the staminate inflorescences (catkins) and shedding of pollen increase or hasten with rising temperatures and associated lower relative humidity. Rainy weather has the opposite effect and reduces pollen dispersal. In oaks, pollen dispersal occurs when relative humidity remains below about 50 percent for 3-4 hours (Sharp and Chisman 1961, Wolgast 1972). We don't have that detailed information for black walnut, but it can be readily gathered. For instance, monitoring the weather at an orchard site during the expected pollination period means that fewer variables are left to guesswork, making it easier to predict the success or failure of the nut crop.

Probably the most important factor controlling the emergence of pistillate flowers and their receptivity is temperature, through its direct or indirect effects on branch and leaf elongation. However, until we begin to work with clonal propagules to reduce genetic variation, an evaluation of flowering, fruit set, and nut yield of the currently planted walnut wild types in relation to low temperatures will remain inconclusive. Low temperatures in the spring may not affect flowering unless there is a hard enough freeze to damage shoots and leaves.

Floral sex ratios can change with site conditions. Variation in temperature along a site gradient can influence the physiological basis for sex allocation. In a study of oaks (Aizen and Kenigsten 1990), only stems at the top of the slope had mature fruits, apparently related to the increase in pollen availability at the top of the slope (higher air temperatures and lower relative humidity). Therefore, where we plant our trees can have a dramatic effect on nut production. If a planting site is chosen because of its deep, well-drained soil, but it happens to be in a frost pocket, the trees will not be happy!

NEW INFORMATION ABOUT FLOWERS

A significant contribution to our understanding of floral biology in eastern black walnut occurred with the publication by Schaffer et al. (1996). Their objective was to obtain information on the development of the pistillate (female) flower of the cultivar Ogden from early stages of differentiation to fertilization. Examining how many topics in Table 1 and Table 2 they observed shows a quick test of their success. Various perspectives of the pistillate flower structure are shown in Figures 1-4 (Schaffer et al., 1996).

Bract development, the first sign of a differentiating flower, was observed by Schaffer et al. (1996) in terminal buds collected in late February. Flowers at the same developmental stage were found in over wintering buds of protandrous cultivars of English walnut (Polito and Li 1985). By mid-April, sepal and pistil development was visible in cv. Ogden. Sepals and bracts will eventually form the husk of the walnut fruit. The pistil differentiated into the stigmas, styles, and ovary. The ovary, within which ovule formation occurs, is at the base of the pistil. The outer portion of the ovule differentiates into the integument while the central portion becomes the nucellus. Simultaneously, the integument elongates to surround the nucellus, which produces the embryo sac.

A small aperture remains open at the tip of the integument through which the pollen tube can reach the embryo sac to fertilize the egg. As the integument and embryo sac differentiate, the stigma and style tissues also elongate and enlarge. Although numerous pollen grains were observed on the stigmatic lobes in early May, no pollen tubes were seen. One study of J. regia indicates that fertilization occurs 2-5 days after pollination (Nast 1935). Collections of cv. Ogden made during the week of May 18 included fertilized flowers containing endosperm tissue. By this time, the cv. Ogden stigmas were fully expanded and exhibited dry, necrotic areas. Stigmas that are dry or necrotic cannot function as a transport medium for pollen tubes (Masters 1974, Polito 1985). Although these pistillate flowers emerged in late April and their stigmas were fully expanded in early May, further internal differentiation of flowers continued after they emerged.

Up until now, this discussion has been related to pistillate flower development. What about staminate flowers found along the length of the staminate inflorescence or catkin? The paper by Schaffer et al. (1996) does not supply much new information about these structures. The male flowers begin to differentiate early in the summer of the year before blooming (Funk 1970) and are found in cone-shaped buds that are apparent by early autumn along the previous year's branches. These "male" buds tend to be found at the distal end (furthest from the base) of the branches (Figures 5, 6). Pollen-related studies in trees tend to lag behind those of pistillate flowers, at least until there is recognition that pollination is critical, or even limiting, to the entire process of seed production. However, because the pollen is dispersed by wind, the pollen source for the pistillate flowers remains difficult to control.

Prediction of Flowering

Can we predict the size or presence of a walnut flower crop 6 months or a year in the future? At the moment, the answer is probably not. If we need an estimated 2 weeks before the expected date of flower emergence, then the information is easily obtained by dissecting terminal buds and searching for the pistillate flowers. An estimated 2 months ahead of the flowering date will require a little more creativity. For instance, we could make the assumption that, once a flower is initiated, the pathway for its development will be continuous and successful. This "all-or-none" hypothesis can be tested by sampling a population of buds in late winter and counting the inflorescence primordia with a dissecting microscope. In early spring, sample branches from the same tree(s) could be put into bottle culture indoors, forcing the buds to flush so that flowers could be observed. The number of flowers and inflorescences could be observed, and these values could be compared to flower numbers from intact branches on the source tree later in the spring. A significantly lower flower count at anthesis could indicate that either the differentiation process was disrupted or the sampling was inadequate.

Research on annual plants has shown that many genes regulate flower development (Bowman et al. 1989, Shannon and Ry Meeks-Wagner 1991, Smyth et al. 1990). Today, it is not unreasonable to assume that genes with the same construct as in annuals, or genes with similar structure, control the development of various flower components in trees. Therefore, an alternative hypothesis, and one that is probably more realistic, is that there are many independent steps to successful flower emergence, beginning with inflorescence initiation. At each step there is some potential for a proportion of the flowers to abort. Testing for the expression of specific gene activity requires both traditional breeding protocols and current molecular technologies, such as DNA hybridization, RAPD (Randomly Amplified Polymorphic DNA), and PCR (Polymeric Chain Reaction). Unfortunately, a constraint with breeding trees is the many years required for the progeny to flower, i.e., we must wait for the juvenile-mature phase change to occur. It is generally accepted that the change from a juvenile to a mature state in forest trees occurs at the time of first flowering (Zimmerman 1972, Poethig 1990).

Current molecular technologies that use vegetative tissues to identify the expression of specific genes may overcome some of the time constraints. For instance, Weigel and Nilsson (1995) isolated a gene that regulates early flowering (precocious flowering) from an annual plant and then inserted the gene into a Populus tree via an Agrobacterium transformation procedure. Weigel and Nilsson produced transgenic plants of Arabidopsis in which the flower-meristem-identity gene LEAFY (LFY) was constitutively expressed. They demonstrated that LFY encodes for a developmental switch that can convert all lateral shoot primordia into solitary flowers so that flowers are produced precociously. The effects on the main shoot are modulated by day length, suggesting that meristems must acquire some competence to respond to LFY activity. Activity of the APETALA1 (AP1) gene can also turn vegetative meristems into flowers (Mandel and Yanofsky 1995). The normally indeterminate shoot apex of Arabidopsis becomes a floral meristem and forms a terminal flower in the AP1 transgenic plants. The AP1 gene alone can convert inflorescence shoots into flowers, even though AP1 is not normally absolutely required to specify floral meristem identity. Thus, both the LFY and AP1 genes can convert vegetative meristems into flowers. Mutations in the AP1 gene attenuate the phenotype of LFY-transgenic plants, but not the reverse combination, suggesting to Mandel and Yanofsky (1995) that AP1 acts “downstream” of LFY to specify meristem identity, and that one of the meristem-identity roles of LFY may be to activate AP1. Ectopic AP1 activity significantly reduces the time to flowering and reduces the delay to flowering of long-day plants in short-day conditions. The authors could not conclude if the early flowering phenotype was a direct consequence of AP1 activity at the shoot apical meristem, or was an indirect result of altered plant growth and metabolism caused by altered activity of “downstream” genes regulated by AP1. For those of us in the tree “flowering business,” the discovery and use of these flowering genes are the most exciting pieces of information to appear for many years.

How do you get a tree to pass more quickly from the juvenile to the mature phase? A common strategy is to grow seedlings in an environment that greatly increases growth rate. Some of the cultural methods include elevated temperatures, long photo periods, adequate water, and fertilization. Size per se, especially within a family, is positively correlated with precocious flowering (Cecich et al. 1994); that is, the tallest seedlings in a family (those siblings produced by the same mother tree) are most likely to flower before their shorter siblings. There is no guarantee of this, only the increased chance that they will flower earlier than the short seedlings. The inheritance of precocious flowering has been demonstrated in many forest trees (Chalupka and Cecich 1997). Because precocious flowering is an inherited trait and is positively correlated with height, selection pressure can be applied to increase the frequency of progenies that flower early by selecting only the tallest 25 or 50 percent of the seedlings. If precocious flowering walnut trees can be identified and selected, it should be possible to attain future generations or lines relatively quickly.

Precocious flowering was noted by Mr. Wayne Lovelace at the Forrest-Keeling Nursery in Elsberry, MO, as he developed a protocol to remove the taproots of oak seedlings for easier handling in the nursery. One unexpected product of the protocol, known as the root production method (RPM®), is that the juvenile phase of the seedlings is greatly reduced; the plants flower in 2-3 years from seed instead of in 15-20 years. The RPM protocol is currently being tested on black walnut, but results are not yet available.

Supplemental Mass Pollination (SMP) has been used for several years in the southeast United States (Bridgewater et al. 1987). Since the annual requirement of millions of genetically improved seeds cannot readily be produced with controlled pollination bags, this alternative is being tested. The essence of the technique is to spray large amounts of select pollen at the orchard trees with a mobile pump at critical flower developmental stages; that is, when the ovulate strobili ("female flowers") are receptive. In theory, contamination from airborne, non-select pollen may be acceptable because it should account for only a small percentage of the pollen reaching the females. Therefore, a large percentage of the potential genetic gain due to the pollen source should be attained. However, some of the continuing research of Bridgewater et al. indicates that the SMP pollen may be less competitive than airborne pollen in causing fertilization.

Can this approach work with walnut trees? Possibly. However, there will always be a need to evaluate some of the implications noted with the pine seed orchards. For instance, certain Juglans regia cultivars abort significant numbers of their flowers. The problem, known as PFA (pistillate flower abscission), seems to be caused by high pollen loads on the stigmas (McGranahan et al. 1994). Flowers receiving high pollen loads abscise from the tree before the unpollinated flowers. A similar response with poor nut set in black walnut (Beineke and Masters 1976) was attributed to too much pollen in the pollination bags. There is not yet a definitive answer to whether too much pollen on black walnut stigmas is a cause of flower abortion. A test whereby incremental increases in pollen are put onto flowers in pollination bags could easily be done on clonal material, so as to reduce tree-to-tree variation.

Until recently, attempts to repeatedly induce flowering in hardwoods have failed. This included the application of mineral fertilizers, which seem to have no direct effect on flowering, although there may be an indirect effect from a correlated increase in crown size or vigor. However, Jones et al. (1995) applied mineral fertilization (granular NPK, 13-13-13) in late summer for 5 consecutive years. During those years, there was a 48-percent increase in nut production on trees receiving the fertilizer compared to the control trees that were not fertilized. Spring fertilization had no statistically significant effect on nut production. In a follow-up study, Gray (1997) found that low levels of ammonium or nitrate N, applied in spring or fall, had a positive, but not significant, effect on the number of pistillate flowers found. Although the fertilized trees produced 2.3 to 3.4 times as many females as the controls, there was too much tree-to-tree variation to detect any statistical difference. The need to control variation is an important argument for using clonal propagules in future walnut orchards or plantings.

Another potential source of good news for the black walnut industry is being nurtured in Indiana. The USDA Forest Service - North Central Research Station and Purdue University, in conjunction with several other organizations, are developing a hardwood biotechnology research and technology transfer program. Black walnut will be one of the species studied. Precocious flowering will be one of the initial research problems because of its requirement for completely testing the products of genetic engineering. There will be an active technology transfer component of this program, funded by the Forest Service's State and Private Forestry division, so that new results are made available to the states as quickly as possible.

Where do we go from here? Tables 1 and 2 show briefly where we have been and what remains to be done. For instance, all we can discuss with confidence about staminate flowers is that they occur on 1-year-old branches and we have observed pollen dispersal when the relative humidity was low on warm days. We have made progress in understanding pistillate flower development (Schaffer et al. 1996), but we still don't know when the pistillate flower is initiated. The efficacy of flower-inducing techniques will revolve around that one piece of information. The paper by Schaffer et al. (1996) provided some data related to embryology, the earliest stages of seed development. The differentiation of the walnut seed remains to be explored. Although we have made progress in the last 10 years, there is still much research to be done to answer the questions about flowering.

TABLE 1. A classification scheme for studying the floral biology of black walnut.

	TO DO# 1989	TO DO# 1998
I. STAMINATE FLOWER		
Initiation of inflorescence	*	*
Differentiation of inflorescence	*	*
Initiation of floral meristems on the inflorescence	*	*
Differentiation of floral meristems	*	*
Bracts, perianth, filament, pollen sacs, pollen grains		
Emergence of staminate flowers		
Elongation of inflorescence (Catkin)		
Dispersal of pollen		
Germination of pollen	*	*
Pollen tube growth	*	*
II. PISTILLATE FLOWER		
Initiation of inflorescence (Peduncle)	*	*
Differentiation of inflorescence (peduncle)	*	*
Initiation of floral meristem	*	*
Differentiation of floral meristem	*	
Bracts, involucre, sepals, pistil, stigma, style, ovary, ovule	*	
Emergence of pistillate flowers		
Continued differentiation of flower parts	*	
Receptivity of stigmas		

TO DO# indicates the processes that had not documented in 1989 and have not been documented as of 1998. The progress in the last 10 years has been in understanding the differentiation of the pistillate flower before and after emergence.

Table 2. The anatomical and structural components of eastern black walnut seed development.

	TO DO# 1989	TO DO# 1998
III. EMBRYOLOGY		
Nucellus	*	
Integument	*	
Megaspore mother cell	*	*
Meiosis	*	*
Embryo sac ontogeny	*	*
Fertilization	*	*
Endosperm ontogeny	*	
Embryo ontogeny	*	
III. SEED DEVELOPMENT		
Cotyledon Enlargement	*	*
Starch deposition	*	*
Lipid deposition	*	*
Protein deposition	*I	*
Embryo Axis Development	*	*
Apical meristem	*	*
Stele	*	*
Root meristem	*	*
Husk and Shell Development	*	*

TO DO# indicates the processes that had not been documented in 1989 and have not been documented as of 1998. The progress in the last 10 years has been in understanding the differentiation of the pistillate flower before and after emergence.

LITERATURE CITED

Aizen, M.A., and A. Kenigsten. 1990. Floral sex ratios in scrub oak (Quercus ilicifolia) vary with microtopography and stem height. Can. J. Bot. 68: 1364-1368.

Beineke, W.F., and C.J. Masters. 1976. Controlled pollination in black walnut. Purdue Agric. Expt. Sta. Publ. 6532.

Bernier, G. 1988. The control of floral evocation and morphogenesis. Ann. Rev. Plant Physiol. and Plant Molec. Biol. 39: 175-219.

Bowman, J.L., D.R. Smyth, and E. M. Meyerowitz. 1989. Genes directing flower development in Arabidopsis. The Plant Cell 1: 37-52.

Bridgewater, F.E., D.L. Bramlett, and F.R. Matthews. 1987. Supplemental mass pollination is feasible on an operational scale. In Proc. 20th Southern Forest Tree Improv. Conf. pp. 216-222.

Cecich, R. A. 1989. Flowering--what we do and mostly don't know. In (Phelps, J.E., ed.) The Continuing Quest for Quality. Proc. Fourth Black Walnut Symposium. Carbondale, IL; July 30-August 2, 1989. pp. 237-241.

Cecich, R.A., H. Kang, and W. Chalupka. 1994. Regulation of early flowering in Pinus_banksiana. Tree Physiol. 14: 275-284.

Chalupka, W., and R.A. Cecich. 1997. Control of the first flowering in forest trees. Scand. J. For. Res. 12: 102-111.

Farmer, R.E., Jr. 1981. Variation in seed yield of white oak. For. Sci. 27: 377-380.

Funk, D.T. 1970. Genetics of black walnut (Juglans nigra). U.S. Dept. Agric., Forest Service. Res. Paper. WO - 10. 13 p.

Gray, D. 1997. Black walnut fruit yield components: Effects of N form and timing of application. Columbia, MO: University of Missouri. 134 p. Thesis.

Jones, J.E., H.E. Garrett, J. Haines, and E.F. Loewenstein. 1995. Genetic selection and fertilization provide increased nut production under walnut-agroforestry management. Agroforestry Systems 29: 265-273.

Linit, M.J., and S. Necibi. 1995. Black walnut curculio: patterns of nut damage in a plantation environment. Agroforestry Systems 29: 321:331.

Mandel, M.A., and M.F. Yanofsky. 1995. A gene triggering flower formation in Arabidopsis. Nature 377: 522-524.

Masters, C.J. 1974. The controlled pollination techniques and analysis of interspecific hybrids for black walnut (Juglans nigra L.). West Lafayette, IN: Purdue University, 161 p. Dissertation.

McGranahan, G.H., D.G. Voyiazis, P.B. Catlin, and V.S. Polito. 1994. High pollen loads can cause pistillate flower abscission in walnut. J. Amer. Soc. Hort. Sci. 119: 505-509.

Nast, C.G. 1935. Morphological development of the fruit of Juglans regia. Hilgardia 9: 345-362.

Poethig, R.S. 1990. Phase change and the regulation of shoot morphogenesis in plants. Science 250: 923-930.

Polito, V.S. 1985. Flower differentiation and pollination. In (Ramos, D.E., ed.) Walnut Orchard Management. Cooperative Extension, Univ. California, Division of Agriculture and Natural Resources, Oakland. Publ. 21410. pp. 81-86.

Polito, V.S., and N. Li. 1985. Pistillate flower differentiation in English walnut (Juglans regia L.): a developmental basis for heterodichogamy. Sci. Hortic. 26: 333-338.

Schaffer, K.L., M.F. George, M. Peleg, H.E. Garrett, and R.A. Cecich. 1996. Pistillate flower development in eastern black walnut. Can. J. For. Res. 26: 1514-1519.

Shannon, S., and D. Ry Meeks-Wagner. 1991. A mutation in Arabidopsis TFL1 gene affects inflorescence meristem development. The Plant Cell 3: 877-892.

Sharp, W.M., and H.H. Chisman. 1961. Flowering and fruiting in the white oaks. I. Staminate flowering through pollen dispersal. Ecology 42: 365-372.

Smyth, D.R., J.L. Bowman, and E.M. Meyerowitz. 1990. Early flower development in Arabidopsis. The Plant Cell 2: 755-767.

Weigel, D., and O. Nilsson. 1995. A developmental switch sufficient for flower initiation in diverse plants. Nature 377: 495-500.

Wolgast, L.J. 1972. Mast production in scrub oak (Quercus ilicifolia) on the coastal plain in New Jersey. New Brunswick, NJ: Rutgers University. 137 p. Dissertation.

Zimmerman, R.H. 1972. Juvenility and flowering in woody plants: a review. Hortscience 7: 447-455.

DEFINITIONS

Primordium: Undifferentiated tissue, usually found in a bud, that will develop into a specific tissue or organ.

Inflorescence: A structure on which one or more flowers are formed.

Axillary: The position that a flower or bud occupies in the acute angle formed by a leaf petiole and the stem.

Terminal: The position located at the end of a branch.

Pistillate Flower: A reproductive structure in which the egg develops.

Staminate Flower: A reproductive structure that gives rise to pollen and the male gamete.

Fecundity: The quality of having attained the ability to sexually reproduce.

Precocious Flowering: An exceptional flowering event that occurs much earlier than the average age for that species.

Missouri Eastern Black Walnut Breeding Program

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INTRODUCTION

Eastern black walnut (Juglans nigra L.) is native to Missouri and is valued for both the quality of its timber products and nut production for human consumption. A fledgling nut industry based largely on wild germplasm and a few small-scale growers has become established. Generally, harvested nuts are either marketed directly to the consumer or sold to Hammons Products Company for processing. Further commercial development of the industry will require an increased role for the Missouri nursery industry as a supplier of superior cultivars on grafted rootstock.

Developing new eastern black walnut cultivars is a long-term process and its impact on the black walnut industry may not be felt for 20 years after the initiation of a breeding program. Justification for the existence of a breeding program is based on its role in increasing the efficiency of industry integration through the generation of improved cultivars and information pertinent to germplasm recommendations.

Resources need to be applied to three areas to sustain the growth of eastern black walnut as a viable crop: 1) orchard management practices, 2) product development, marketing, and promotion, and 3) cultivar development and evaluation. Simultaneous advancement, in an interactive manner, on all three fronts is essential if the industry is to grow. Development of alliances among nurseries, growers, processors, government agencies, and the University of Missouri will facilitate the rapid economic expansion of this crop.

Immediate impact can be effected through improved orchard management practices and well developed marketing strategies that include all parties from nurseries to consumers. Establishing a black walnut grower's cooperative to serve as a focal point for the dissemination of extension services and product distribution is highly desirable. The cooperative can foster industry integration by improving communication among the nursery industry, growers, and processors. The benefits of industry integration include the standardization to a set of cultivars resulting in increased efficiency from an economy of scale to each entity, and identification of germplasm deficiencies, making it easier for a breeding program to define relevant traits and target audiences. Hammons Products Company strong position in the processing and marketing of nut meats dictates that it take a leadership role in shaping the integration of this industry.

CULTIVAR DEVELOPMENT

Increased yields of a high quality product result from a combination of improved cultural practices and the development of superior cultivars. Cultivar development is a process of engineering design motivated by a need to address production problems through the creation of better adapted germplasm. Implicit in this process is the importance of a precise definition of the target environment. The environment includes not only climatic and edaphic features, but also the end-product use, size of the industry, degree of capital investment, and intensity of management.

The major issues for defining the target environment of a black walnut breeding program center on grower's objectives. The relative importance of nut and timber production must be clearly established and a strategy for achieving these objectives must be delineated. For example, if growers want both nut and timber production they could either 1) dedicate separate acreage to nut or timber trees, 2) intercrop nut and timber trees in alternate rows, 3) high graft superior nut producing cultivars onto superior timber producing understock, or 4) grow trees that are superior for both timber and nut production. Cultural practices are strategy dependent and are an important component of the environment. Therefore, strategy needs to be specified before selection for improved genotypes can proceed. Also, the timber industry must be consulted about their receptivity to purchasing trees grown under each of the strategies.

There is controversy surrounding the fourth strategy. This controversy concerns the feasibility of selecting a cultivar genetically superior for both nut and timber production. Since nut (reproductive) and timber (vegetative) traits represent competing resource sinks, negative genetic correlations may exist between them. Consequently, it would be difficult to optimize both traits simultaneously. However, it is unlikely that the correlation would be perfect. Also, the nut and timber industries currently use wild unimproved germplasm. It is reasonable to expect that cultivars could be developed that are superior, for both nut and timber production, to what is currently used by either the nut or timber industries. A more pressing concern is whether or not the management practices for nut and timber production are compatible. Once suitable management practices for this strategy are identified an appropriate selection scheme could be devised. The long term outlook, though, is that single purpose trees will be better suited for their market niche than dual purpose trees and the industry needs to consider this eventuality.

Germplasm Evaluation

Three tasks critical to the successful initiation of a black walnut breeding program are: definition and prioritization of relevant traits, establishment of a multi-location cultivar evaluation trial, and initiation of a rootstock evaluation trial. Breeding for improved cultivars and rootstock will draw on data obtained from the evaluation trials to set program goals and establish benchmarks.

Trait definition - A breeding program(s) progress is inversely related to the number of independent traits being improved (i.e., for n uncorrelated traits under selection genetic gain will be only $n^{-0.5}$ as great as the gain for a single trait under selection, assuming equivalent genetic parameters). Selection pressure is diluted by the inclusion of each additional trait. Therefore, it is imperative that a breeding program clearly prioritize, and periodically review, those traits being improved. Although the number of traits to which selection pressure is applied must be minimized, many other traits need to be monitored as they also directly impact product quality. Important horticultural traits are: anthracnose resistance, vigor, consistency of nut yield, percent lateral fruitfulness, nut shape, and nut quality (shell thickness, percent crack out and ease of crackability, kernel weight, kernel plumpness, kernel color, flavor and kernel oil content). Timber quality is also a composite of several traits--straightness of bole and specific gravity being the most important traits. Phenological traits are critical to crop productivity. These include leafing date, first pollen shed, last pollen shed, peak female bloom, and harvest date. Ideally, data should be collected on all of these traits for each individual tree in a breeding program. Practically, compromises need to be made because resources are limited.

Multi-location cultivar trial - Baseline data on existing cultivars are needed to provide recommendations to growers and determine limitations of existing germplasm for particular environments. These data should be from a cultivar trial using grafted rootstock of cultivars grown in common orchards and replicated across diverse environments. The primary goal of the variety trial is to determine the extent of genotype stability. Secondarily, the cultivar trial should determine the optimal genotype and cultural practice for the various geographic regions of Missouri. Breeding strategies based upon these data will permit a more efficient targeting of production deficiencies amenable to genetic improvement. Sites chosen for the variety trial should meet the following criteria: they should sample the diversity of environments confronting the Missouri grower, be relevant to the maximum number of growers, and be placed in accessible locations (collection of phenological data is especially sensitive to the last criterion).

The Missouri Department of Conservation (MDC) has divided Missouri into 5 distinct ecological zones related to walnut production. The variety trial should be designed in three sites that captures most of the variability among these five zones. In addition, the trial also should be conducted in an agroforestry environment and compare the effects of cover crops and rootstock selections on cultivar stability.

Rootstock evaluation trial - Converting seedling orchards to plantings of grafted trees transformed the Persian walnut (J. regia) into a major agricultural commodity in California. This transformation occurred about 1915. The resultant uniformity of horticultural traits within orchards increased yields and promoted the development of good horticultural practices that further advanced the industry. Currently, seedling rootstocks represent the state-of-the-art in orchard management practices. However, research is currently underway to develop efficient clonal propagation techniques for rootstocks, which will further optimize orchard productivity.

The Missouri black walnut industry must undergo a similar transformation if it is to reap the benefits of the California model. The availability of proven rootstocks is a prerequisite to the conversion to grafted tree orchards. Although seedling rootstocks are available from nurseries (Starks Bros. promotes open-pollinated seedlings of Kwik Krop), there is very little or no information about performance and sources for superior rootstock. A good rootstock must be hardy and vigorous but not promote vegetative growth over reproductive potential. It must be evaluated across environments so that recommendations may be made with confidence.

The lack of information on black walnut rootstocks dictates that a rootstock evaluation trial be more limited in scope than the cultivar trial. A good strategy for evaluating sources of rootstocks is to examine the general vigor of a broad range of genotype sources at a single site for two years and cull out obviously deficient germplasm. The success of the Paradox rootstock in the California industry suggests that interspecific hybrids (e.g., J. hindsii x J. negri) also should be evaluated.

The next step in a rootstock evaluation trial is to choose sites that sample a variety of environments and evaluate a select group of rootstock sources across these sites. Evaluation at this step should be made by grafting scion from at least two different cultivars to each rootstock source and observing vigor, yield and phenological traits of the grafted trees. Walnuts can be grown on soil types ranging from the extremes of sandy to heavy clay loams and from thin to deep soils. However, it should not be assumed that the same rootstock will be optimal for all soil types. Therefore, site selection should reflect soil diversity. Also, a site that challenges rootstock cold hardiness would provide valuable information for northern Missouri growers. The effect of cover crop on rootstock performance (e.g., is there variability for production of mycorrhizae among selected rootstock sources? Is such variability reflected in the variability of nut and timber traits?) must be included as a treatment effect at each site .

A complication in evaluating rootstock seedlings is the contribution of the pollen parent to seedling traits. At least some control needs to be placed on the pollen source since distinctly different progeny can result from the same cultivar when it is pollinated by different genotypes. Failure to control pollen source will reduce the stability of rootstock performance and may also confound the evaluation scheme. (The situation is avoided in the cultivar trial because most nut characteristics, excluding the embryo, are determined only by the maternal genotype.) If it is not feasible to do control pollinations or use common seed orchards, then rootstock seed should be collected from a single site for each genotype source.

Information obtained from the cultivar and rootstock trials will indicate if there is a significant scion-by-rootstock interaction for black walnut. Whether or not cultivars and rootstock need to be selected in tandem will be based on the magnitude of this interaction.

Selection and Hybridization Program

A breeder must be aware of the biological constraints to developing a successful breeding program. The salient features of eastern black walnut biology are: 1) generation times are long--time to first flower is at least four to six years; 2) it is a heterozygous cross-pollinated species that undergoes a marked reduction of vigor and productivity with inbreeding; 3) flowering is dichogamous and bloom period lasts only a few weeks; 4) flowers are wind-pollinated; 5) pistillate flower abscission (pfa) from an over-abundance of pollen has been observed; 6) seed germination requires 3 to 4 months of cold stratification; and 7) vegetative propagation by cuttings (grafting) is feasible.

The long generation time of eastern black walnut dictates that a selection and hybridization program be initiated concomitant to the cultivar and rootstock evaluation trials. Therefore, the program needs to be flexible enough to accommodate new information generated by these trials without disrupting progress made through selection. A recurrent selection program initiated with a broad base of unrelated superior cultivars, using controlled matings and minimizing inbreeding, has the best chance of long term success. (Such a program is labor intensive and it may be necessary to scale back to a scheme using open-pollination in isolated seed orchards. The drawback to doing so is that progress is reduced and it is more difficult to track inbreeding.) The peculiarities of walnut floral biology reduces the efficiency of controlled crossing. Therefore, it may take several seasons to complete a crossing scheme. Dominant gene action can be captured through vegetative propagation so broad sense heritabilities are appropriate for planning breeding strategies.

Selection - Specification of important traits (see section II.A.1) must be completed before parents can be selected. An attractive breeding approach for perennials with long juvenility periods is to combine independent culling and index selection in a two stage selection procedure. This is accomplished, for example, by first doing a greenhouse seedling screen for anthracnose resistance, culling out susceptible genotypes, followed by a field planting of the resistant types. Field trees are then evaluated for the desired traits (a key assumption is lack of linkage between anthracnose resistance and other traits) and trees ranked based on a phenotypic index of these traits. If necessary, several indices can be constructed to accommodate the requirements of different geographic regions. For example, northern Missouri sites might require a later date of leaf flush (and accompanying flowering) than southern sites. Increasing the selection intensity results in greater gain per selection cycle but also increases the rate of inbreeding. Consequently, selection intensity needs to be balanced with the program(s) anticipated number of selection cycles.

Mating design - Factorial mating designs (e.g., NCII) serve the dual purpose of combining germplasm in a controlled manner and providing the appropriate family structure for genetic analysis methodology. The main disadvantage of the factorial design is the difficulty in obtaining a balanced set of progeny from each family. Particular sets of crosses may be difficult or impossible to make. If extensive sets of crosses do not produce seed, then entire crossing blocks could be lost to analysis. Large crossing blocks provide more reliable information about each parent but are more difficult to complete. Considering the difficulty in making controlled crosses with black walnut, a 3x3 crossing block size may be optimal. Eight 3x3 crossing blocks, a total of 48 parents, would require three generations to completely introgress the original parents into a common germplasm pool. Progeny from each generation would be evaluated for possible cultivar release.

ANCILLARY RESEARCH

MDC Black Walnut Progeny Testing Program

The MDC has established a wide ranging progeny test covering multiple sites. Data have been collected on several timber quality traits for a varying number of years for this project. Evaluation and analysis of these data could provide valuable information regarding genotype-by-environment interactions of black walnut vigor. Also, some of the MDC selections may be suitable for inclusion in the breeding program.

Other Research

Several lines of research need to be pursued to increase the efficiency of a black walnut breeding program. The following are some examples of research that could directly impact a breeding program:

> **Anthracnose resistance** - Defoliation by anthracnose infection affects nut fill and is implicated in yield reduction of the subsequent years crop. It is the most destructive foliar disease of black walnut in Missouri. Currently, only cultivars resistant to anthracnose infection are suitable for release. The inheritance of anthracnose resistance has been investigated by Dan Neely and others, but individual resistance genes have not been identified yet. Establishing the Mendelian basis of anthracnose resistance can greatly increase the selection efficiency for this trait because it determines the population size of seedlings that needs to be screened. Development of a seedling resistance screening technique suitable for a selection program is another benefit obtained from a genetic study of anthracnose resistance.
>
> **Micro-propagation** - Black walnut is considered to be a difficult species to vegetatively propagate by rooting. Developing a convenient and reliable micro-propagation technique for black walnut will greatly enhance our ability to evaluate rootstock and permit the development of clonaly propagated rootstocks. Jerry Van Sambeek is currently developing a micro-propagation technique based on rooting of stem cuttings. Collaboration with him will ensure that the technique is optimized for genotypes important to the breeding program.
>
> **Morphology of nut architecture** - Ease of crackout is an important trait in nut production, and cultivars vary widely for this trait. Measuring the dimensions of various

morphological characteristics observed in cross- and longitudinal-sections of a sample of nuts from various cultivars may reveal which features are most strongly correlated to crackability. A multivariate statistical analysis (e.g., principal component analysis, canonical correlation analysis, and discriminant analysis) may lead to the development of a selection index for crackability. Additionally, detailing the morphological characteristics of nut architecture may expedite cultivar identification. For example, it may be possible to determine whether or not 'Mintle' and 'Brown Nugget' are different cultivars based on nut morphology.

Genetic variability of wild germplasm - Although the black walnut industry should be encouraged to move from using native seedling selections to elite germplasm, it is still necessary to maintain and catalogue species diversity. This is important because it is sometimes necessary to infuse a breeding population with new germplasm to minimize inbreeding. Isozyme analysis is a useful tool for screening wild germplasm to select the best genotypes for inclusion in a breeding program. The technique has been developed for black walnut by George Rink. Sampling black walnut germplasm throughout its native range and cataloging its isozyme diversity will be a useful addition to the morphological data that has already been collected.

Inter-specific hybrids - Several investigators have initiated studies into the hybridization of the Persian and eastern black walnut (J. regia x J. negri). Potential advantages to this line of research are the development of thin shelled black walnuts and higher yielding black walnut trees. Rootstocks are another potential use for inter-specific hybrids. J. microcarpa is better adapted to high pH and calcareous soils than is J. nigra. A hybrid of these two species, used as a rootstock, may show increased vigor and extend the productive range of J. nigra into thin calcareous soils.

Black walnut juvenility - The long generation times of black walnut are a major obstacle to tree improvement through breeding. Research aimed at developing convenient techniques to reduce the time from seed germination to flowering could pay great dividends to a breeding program. Much research has been done with other crops in this regard, most notably with apple.

Variability of juglone concentration among black walnut genotypes - The phytotoxic nature of juglone (5-hydroxy-1,4-napthoquinone) is well known. However, the magnitude of its role as a phytotoxin in an agroforestry environment has not been demonstrated. Also, the inhibitory effects of juglone on insect populations is not well understood. Investigating the variability of juglone concentration in roots, foliage, and husks among genotypes of black walnut is the first step to understanding its ecological role in the orchard environment. Understanding this role is a critical step in deciding the importance of juglone concentration as a trait to be monitored in a breeding program. An HPLC assay for juglone (and its precursor, hydrojuglone glucoside) in black walnut leaves and husks has been developed by Steven Cline and Dan Neely.

Genetic correlations and heritabilities of black walnut traits - Reliable estimates of genetic parameters require establishing breeding populations of sufficient size and family structure. These estimates are used to predict genetic gain from selection programs, define selection indices, and determine if a program should be infused with new germplasm.

Kernal color measurement - Nut quality and value is directly related to kernal color. Developing an objective, precise, and automated protocol for kernal color measurement based on spectrophotometry will facilitate nut grading by processors. It also could lead to the development of a differential pay scale to growers based on the nut quality of their crop. A breeding program could use this technique to investigate cultivar post-harvest color stability.

Dwarf trees - Size reduction of J. nigra trees can lead to increased yields per hectare and decreased labor costs in close plantings. Smaller trees also may provide advantages in an agroforestry setting by reducing the shading of cover crops. Size reduction can be achieved through the selection of trees of smaller size or through the use of dwarfing rootstocks. J. ailantifolia interstocks have been demonstrated to reduce J. regia scion growth.

Flavor variation among cultivars - Establishing the variability for flavor parameters (e.g., sweetness, astringency, and rancidity) of cultivars is an important first step in the industry's move away from wild germplasm. Depending on the magnitude of the variation, profound changes in product quality may result from this move. It is important for the industry to establish consumer preferences for black walnut flavor as it strives to increase the consumer base for this product.

PART 4

CULTURAL PRACTICES FOR EASTERN BLACK WALNUT NUT PRODUCTION

Pruning And Tree Thinning

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THE IMPORTANCE OF SITE QUALITY

Black walnut is very sensitive to soil conditions, developing best on deep, well-drained, nearly neutral soils, which are generally moist and fertile. The better growing conditions are typically located on the lower north and east facing slopes, stream terraces and floodplains. The quality of a site is reflected in its site index rating. Site index is the number assigned which reflects how tall a tree will grow in a certain number of years (usually 50 years). A walnut site index of 80 indicates that location will grow a walnut tree to 80 feet of height in 50 years. Good walnut growing sites produce more useable volume per acre than poor growing sites even where the same number of trees are involved. And, the good sites do it in a shorter period of time.

Brinkman (1966) provides yield data in board-feet-per-acre from various sites (Table 1). The table reveals that walnut on a site index 40 would take 65 years to produce 870 board feet of wood where a site index 80 site could produce it in 25 years.

Table 1. Yields in board feet per acre of black walnut plantations in the north central region by age and site index.* (Trees planted at a 10-foot spacing.)

SITE INDEX

AGE (Years)	40	50	60	70	80
20	--	--	--	--	100
25	--	--	110	380	900
30	--	--	360	1,000	2,200
35	--	200	810	1,930	3,760
40	--	400	1,400	3,300	5,670
45	170	780	2,160	5,100	7,860
50	250	1,200	3,100	6,500	9,820
55	400	1,700	4,150	8,010	11,750
60	630	2,250	5,210	9,380	13,150
65	870	2,800	6,230	10,060	14,400
70	1,060	3,350	7,170	11,620	15,460
75	1,250	3,800	8,000	12,550	18,250

* Volume in board feet per acre (Scribner Rule) of trees 10 inches d.b.h. and larger to an 8-inch top diameter inside bark.

THE IMPORTANCE OF LIGHT

Another characteristic of black walnut which a landowner should know is that it is intolerant of shade. In mixed forest stands it must be in a dominant or co-dominant position with other trees to maintain itself. The intolerance to shade of black walnut is an important factor to consider in several stages of management. If a woodland owner is trying to replant openings created in a natural stand he must be aware that without an opening of at least 1/3 to ½ acre in size a walnut planting will almost always result in failure. Even then, several years of controlling competing vegetation is necessary.

Any trees which are overtopped by less desirable trees in the woodland must be released from shading before they become deformed or are stunted to the point they are unable to respond properly to release.

PROPER TREE SPACING

An important concept for the landowner to understand is that of proper spacing of trees within a woodland. It is not practical to try to grow every tree to maturity so the best trees (crop trees) should be selected at appropriate spacings and managed to improve their form and growth. When a choice is possible, dominant and codominant trees should be favored over intermediate or overtopped trees. Select the fastest growing trees as crop trees where quality form is acceptable. External characteristics such as bark pattern often give a good clue to rate of growth. The reddish-brown inner bark will be visible in the bark fissures on fast-growing walnut trees. Slow-growing walnut trees tend to have flat, platy bark.

Trees that are low forked, have excessively large low branches, or are defective for any other reasons should not be selected as potential crop trees although occasionally these trees may have superior nut production qualities that will warrant their retention. Few woods trees produce large nut crops however, because they do not have well developed tops.

Selected crop trees should have adequate growing space in order to maintain rapid growth. Competing trees may be harvested for products, or simply girdled or injected with appropriate herbicides. All vines should be removed from crop trees because they can stunt, kill or deform desirable trees.

There are many rules of thumb or formulas used to determine proper tree spacing. One rule of thumb commonly used is "the distance between two trees should be average of their inches in diameter at breast height (d.b.h.) changed to feet plus a conversion factor of 8 feet." Example: Trees 4 inches d.b.h. and 8 inches d.b.h. would have an average d.b.h. of 8+4÷2 or 6 inches. Six inches would be changed to 6 feet plus the conversion factor or 8 feet would then give a spacing of 14 feet between trees.

Another rule provides that enough trees should be removed each time a thinning is made to allow the trees to grow about 4 inches in diameter before the tops become too crowded. On most sites this will mean that tree tops should be about 10 feet apart after each thinning.

Stocking levels and spacings recommended by Phares (1973), based on studies by Krajicek, for high-quality veneer logs and good nut production on good sites are shown in Table 2.

It should be noted (Table 2), that if a major emphasis is placed on nut production, additional trees must be removed to further maximize tree crown development. However, open grown trees tend to retain their lower branches indefinitely. Trees that are drastically released from competition may develop epicormic branches (sprouts from dormant buds along the trunk, commonly called water sprouts). These sprouts must also be removed before they also become limbs which will downgrade the log.

Table 2. Tentative stocking guidelines for growing high-quality black walnut on good sites.

			Recommended stocking and spacing after thinning or releasing for different product objectives*			
	Stocking and spacing when crowns begin to touch+		Veneer logs		Veneer logs and nuts	
Average stand d.b.h. (inches)	Trees per acre (number)	Spacing between trees (feet)	Trees per acre (number)	Spacing between trees (feet)	Trees per acre (number)	Spacing between trees (feet)
2	797	7	265	13	225	14
4	380	11	175	16	150	17
6	223	14	125	19	105	20
8	147	17	90	22	80	23
10	104	20	70	25	60	27
12	78	24	55	28	50	30
14	60	27	45	31	40	33
16	48	30	40	33	35	35
18	39	33	35	35	30	38
20	32	37	30	38	25	42
22	27	40	--	--	--	--
24	23	43	--	--	--	--

+ Obtained by using the following equation (Krajicek 1996): crown width in feet = 1.993 d.b.h. in inches + 4.873.

*These values are based on the assumption that crop trees will grow 4 inches in diameter before they again need to be thinned or released.

Many studies indicate that sawtimber-size trees do not respond as well to release and thinning as smaller sized trees so when possible these practices should begin early in the life of the woodland.

CLEAR-STEM PRUNING

A cultural practice which can greatly increase the future value of young walnut trees is clear-stem pruning. By the time a tree has reached 8 to 12 inches in diameter it is often too late for effective pruning because there will not be enough clear wood produced over the pruning wounds to greatly increase log value. Limbs should be removed before they reach 2 inches in diameter to keep the wound being too large for proper healing. A neat, clean cut should be made, preferably with a pruning saw.

Pruning for clear log length can be started when the trees are about 10 to 12 feet tall (Schlesinger and Funk 1977). Wider spacings in open stands will need pruning at an earlier age than more crowded stands. It is recommended that no more than a third of the live crown be removed at any one time. All pruning should be restricted to the lower half of the tree's trunk. Pruning too many branches from the main crown of small trees can slow growth or cause top heaviness with wind breakage resulting.

How high to eventually prune depends on the product objective and on the cost and difficulty of pruning. I would recommend a minimum of 9 to 10 feet of clear butt log to meet minimum veneer requirements. When nut production is a goal, a fairly large crown is needed and therefore the butt log may be the only one pruned.

Current research indicates that the best pruning time is in the late dormant season, just prior to spring growth. Some follow-up pruning will be needed to remove epicormic sprouts which will develop from dormant buds around the pruning wounds. These sprouts should be removed as soon as possible because they, too, will form knots in the wood.

LITERATURE CITED

Brinkman, K.A. 1996. Growth and yield on prairie soils. Pp. 50-52. In Black Walnut Culture. USDA N. Cent. For. Exp. Sta., St. Paul, Minnesota.

Phares, Robert A. 1973. Managing immature trees for more high-quality logs and related products. In Black Walnut As a Crop. USDA N. Cent. For. Exp., St. Paul, Minnesota.

Schlesinger, R.C. and D.T. Funk. 1977. Manager's Handbook for Black Walnut. USDA For. Serv. Gen. Tech. Rep. NC-38. 22 p.

Companion Crop Recommendations for Planting with Black Walnuts

H.E. Garrett and J.E. Jones[1]

The concept of planting trees in widely spaced rows and growing cash crops in the alleyways is a special form of agroforestry called alley cropping. To be successful, the companion crop's physiological requirements (i.e., light, water and nutrients) must be accommodated by the tree. Black walnut's (Juglans nigra L.) foliage and root system are unique and readily adapted to the growth of companion crops. Black walnut is one of the latest species to break dormancy in the spring and is, typically, one of the first to defoliate in the fall. Even with full foliage, it produces a light shade within which many crop species can grow (Garrett et al. 1992). A black walnut's root system is also uniquely designed leading to reduced competition for soil moisture and nutrients between the species and companion crop. Typically, young walnut produce a deep, penetrating taproot which can extend to more than seven feet in the absence of physical barriers. Its long branch roots are found close to the surface but most of the smaller branch and feeder roots turn down sharply leaving a shallow zone near the soil surface for root development of companion crops. When correctly designed, alley cropping with walnut can be highly profitable. Perhaps the most important decision relative to profitability is the choice of companion crop.

COMPANION CROPS

Alley cropping with walnut can be designed to accommodate the biological requirements of most companion crops from those requiring deep shade to those requiring full light. The creation of the proper microenvironment and the timing of its creation are products of selecting the correct tree spacing. In Missouri, there are many examples of crops that have been planted with walnut. The most common, however, are conventional row crops, forages and specialty crops.

ROW CROPS

In an alley-cropping program, shade-intolerant row crops can be established in the alleyways and grown until light, water, or nutrients become limiting from competition (assuming that allelochemicals inhibitory to the crops in question are not produced by the trees). However, since most row crops are shade intolerant, their light requirements must be planned for if they are to be grown for an extended time period. In early research performed by Garrett and Kurtz (1983), upland and bottomland sites were planted with walnut and the alleyways dual cropped with soybeans (Glycine max L.) and winter wheat (Triticum aestivum L.). Trees were spaced 10 feet apart within rows and 40 feet between rows providing 108 trees per acre. Soybeans averaged 24 and 32 bushels/acre on the upland and bottomland sites, respectively, during the first five years. Wheat yields averaged 41 bushels on both sites during the same time frame. While wheat yields changed little between years five and 10, soybean yields decreased by nearly 20%. Due to the percentage change in yields, soybean production was found not to be profitable after the tenth year under the conditions of this early work. While the percentage decrease in yield attributable to increased shade, competition for water and nutrients or allelochemical inhibition is unknown, controlling the competition through the pruning of tree roots or widening the spacing between tree rows can

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extend the life of the cropping regime. Research in Indiana demonstrated a 62% yield increase in corn planted in the alleyways of 8-year-old black walnut from the severing of lateral roots growing into the alleys (Jose et al., 1995).

Studies conducted in Canada on alley cropping black walnut have demonstrated relationships similar to those observed in Missouri (Gordon and Williams 1991; Williams and Gordon, 1992). Intercropping walnut with corn (Zea mays L.) soybeans, and wheat has shown that all can be grown with no obvious inhibition from chemicals produced by the trees. Differences in tree growth responses, however, have been found to be related to the intercrop used. Growth of trees during the first few years was found to be best with corn followed by soybeans (Gordon and Williams, 1991; Williams and Gordon, 1992). Significant reductions in growth were associated with intercropping with small cool-season grains. Differences in growth were believed to be related to differences in soil moisture available to the trees early in the growing season when trees typically do most of their growing. Soil moisture availability was least in the spring when cool-season grain crops were used (Williams and Gordon, 1995). It is reasonable to assume, however, that if sufficient spring rain occurs to recharge the soil profile, this would not be a problem. Moreover, in Missouri and the midwest in general, cool-season row crops (e.g., winter wheat etc.) would seem to be better suited for planting with walnut than warm-season crops. Since weed control is not a problem during the winter and early spring, cool-season crops can be planted closer to the tree rows resulting in less lost production. Also, assuming sufficient rainfall occurs, cool-season crops will normally compete less with trees for water than warm-season crops and create fewer management problems.

FORAGE CROPS

Many forage species, each with unique characteristics, may be used in walnut alley-cropping practices. Selecting a suitable forage species for alley cropping, however, depends on many factors including site conditions, characteristics of the forage, and management objectives. Each of these factors is complex and multifaceted. Since most forage species are adapted to open fields and full sunlight, landowners interested in establishing walnut and forages together must do so with an eye to the future. During the early years, shade will not be a consideration. However, as the trees grow, new microenvironments are established and forage species that are shade intolerant will soon disappear. Therefore, shade tolerance is one of the most important characteristics to consider in selecting a forage for growing with black walnut. Unfortunately, since forages are normally managed under open conditions in the midwest, reliable data on their shade tolerance are lacking. Fortunately, however, recent research by Lin et al. (1998) has demonstrated a number of cool-season forages to be sufficiently shade tolerant to merit use in alley cropping practices (Table 1). While most are untested with walnut, there is a reasonable chance that they would perform well.

Of all grasses, orchardgrass (Dactylis glomerata L.) is most often used in tree plantings in part because it is commonly thought to be shade tolerant and is fairly shallow rooted which minimizes its competition for water with the trees. Red clover (Trifolium pratense L.) is usually the legume of choice. While tall fescue (Festuca arundinacea Schreb.) is also very shade tolerant, it is not widely planted with walnut due to it's deep and prolific rooting characteristics. Timothy (Phleum pratense L.), because of the high quality hay it produces, could become an important companion species for black walnut. In spring-early summer screenings, timothy yields were reduced by 0.33 percent at 50 percent shade. However, even with this reduction, dry matter yields were comparable to that of many of the other cool-season grasses when grown under full sun. Moreover, in late summer-fall trials, yields at 50 percent shade were the same as those in full sun (Lin et al., 1995). Of the other grasses showing shade tolerance, smooth-brome (Bromus inermis Leyss.) is especially prominent in northern Missouri and could offer good opportunities for landowners interested in introducing trees into their pastures.

Great interest has been expressed on the part of landowners in growing alfalfa (Medicago sativa L.) as an alleycrop with black walnut. In Missouri's early trials, alfalfa has performed well under partial shade conditions and would appear to be a viable candidate for planting with trees. However, it has not been sufficiently tested as a companion crop with walnut to merit a recommendation. Alfalfa produces an extensive root system which is more competitive for soil water than many other forage species such as orchardgrass (Chamblee, 1958). Planting alfalfa with walnut could reduce nut yields due to competition for water. Since the generation of income is an important consideration for all landowners, the financial trade-offs of planting alfalfa or any other forage species with walnut must be assessed before recommendations can be made.

The success of any tree/forage practice is directly correlated with the shade and drought tolerance of the forage or forages selected for planting, forage value, the geometric pattern and density of the trees, and the age of the trees. In designing practices, all factors must be considered. Since forages vary in shade tolerance and value, financial gain will, in part, depend upon the ability of the landowner to match the forage species with the correct light regime.

SPECIALTY CROPS

Many niche markets exist for a variety of specialty crops within any locale or region. Alley cropping with walnut can be adapted to include many of these crops. With proper forethought and design, landscaping and Christmas trees species can be grown either within the row (between the permanent trees) or between the rows in the alleyways. Small fruits can be grown for many years with the proper spacing of trees (Garrett et al., 1992). Plants which can be marketed for their medicinal (botanical industry), ornamental, or food values also provide unique marketing opportunities. Species that are light demanding can be established in the alleyways while those requiring some shade can be planted within the row as shade develops.

If one is near a metropolitan area, growing shade-intolerant landscaping species in the alleyways during the early years of a practice can prove to be highly profitable. A viable market, however, is a prerequisite. One should first conduct a survey of the needs of local landscaping firms to determine the market size and species needs before designing the practice. As the trees grow and begin to shade the alleyway, emphasis can change from shade-intolerant to shade-tolerant species, such as redbud (Cercis canadenis L.), dogwood (Cornus florida L.), spruces (Picea spp.), etc.

Many forest botanicals, such as floral greens, ginseng (Panax quinquefolium L.), goldenseal (Hydrastis canadensis L.), mushrooms, etc., are highly valuable, in demand, and compatible with black walnut (Carter, 1996). The fastest growing markets are those for flowers, mushrooms and medicinal herbs. While the quality of many special forest products (i.e., ginseng, goldenseal, etc.) decreases when they are produced under artificial shade, walnut creates a natural shade environment permitting the maintenance of plant quality and value. Moreover, the microclimate requirements of species requiring higher light intensities (e.g., Echinacea, Hypericum etc.), can be created in the alleyways through the proper choice of spacing.

Many specialty markets already exist while others are yet to be developed. Recent studies in the US, that have continued earlier work in Germany, suggest an extract from the leaves of Ginkgo biloba may have medicinal properties (Bricklin, 1995). Assuming such findings are proven correct, new markets will open and Ginkgo foliage could be produced in wide alleyways between rows of black walnut. The possibilities for growing intercrop species, when one looks at the special products market, is almost unlimited but is regional dependent. Landowners should discern local opportunities and select companion crops that best fulfill their goals and objectives and for which markets currently exist or will soon come into existence.

LITERATURE CITED

Bricklin, M. 1995. Herbs that turn back the clock. Prevention 47(7):19-20.

Carter, Z. 1996. Truffling among the trees. Tree Farmer. Sept./Oct. 1996. pp. 12-14.

Chamblee, D.S. 1958. The relative removal of soil moisture by alfalfa and orchardgrass. Agronomy J. 50:587-591.

Garrett, H.E., W.B. Kurtz and J.P. Slusher. 1992. Walnut agroforestry. University of Missouri, MU Guide Sheeet. G5020 4p.

Garrett, H.E. and W.B. Kurtz. 1983. Silvicultural and economic relationships of integrated forestry farming with black walnut. Journal of Agroforestry Systems 1:245-256.

Gordon, A.M. and P.A. Williams. 1991. Intercropping valuable hardwood tree species and agricultural crops in southern Ontario. Forestry Chronicle 67:200-208.

Jose, S., A.R. Gillespie and J.R. Seifert. 1995. The microenvironmental and physiological basis for temporal reductions in crop production in an Indiana alley cropping system. In: Proceedings, 4th North American Agroforestry Conference (J.H. Ehrenreich, D.L. Enrenreich and H.W. Lee eds.). July 23-28, 1995, Boise, ID, pp. 54-55.

Lin, C.H., R.L. McGraw, M.F. George and H.E. Garrett. 1998. Shade effects on forage crops with potential in agroforestry alley-cropping systems. Journal of Agroforestry Systems (in press).

Lin, C.H., R.L. McGraw, M.F. George, H.E. Garrett, B.J. Piotter, and J.L. Alley. 1995. Effects of shade on forage crops that have potential use in agroforestry. Agron. Abstracts. p. 53.

Williams, P.A. and A.M. Gordon. 1995. Microclimate and soil moisture effects of three intercrops in the tree rows of a newly planted intercropped plantation. Agroforestry Systems 29:285-302.

Williams, P.A. and A.M. Gordon. 1992. The potential of intercropping as an alternative land use system in temperate North America. Agroforestry Systems 10:253-263.

Table 1. Shade tolerance of some grasses and legumes with potential for Missouri agroforestry practices.

	Moderately Shade Tolerant		Very Shade Tolerant
Grasses			
Kentucky Bluegrass			
Poa pratensis L.	yes		
Orchardgrass ('Benchmark' and 'Justus')			yes
Dactylis glomerata L.			
Smooth Bromegrass	yes	to	yes
Bromus inermis L.			
Tall Fescue ('KY 31' and 'Martin')	yes	to	yes
Festuca arundinacea Schreb			
Timothy	yes		
Phileum pratense L.			
Red Top	yes	to	yes
Agrostis gigantea Roth			
Reed Canarygrass	yes	to	yes
Phalaris arundinacea L.			
Legumes			
Alfalfa ('cody' and 'vernal')	yes		
Medicago sativa L.			
Berseem Clover	yes		
Trifolium alexandrinum L.			
Ladino Clover	yes		
Trifolium repens L.			
Red Clover	yes		
Trifolium pratense L.			
Striate Lespedeza ('Kobe')	yes		
Kummerowia striata Thumb			

Ground Covers To Maximize Ease Of Management, Tree Vigor, And Ease Of Harvest

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Orchard floor management planning needs to be begin before the walnut trees are planted – long before the trees mature and start producing nuts. Decisions such as number of trees per acre, spacing between and within row, and ground cover management between and within the row are needed before the trees are planted in order to accommodate equipment, future cultural practices, and planning for a sustainable forest operation. Important objectives for whatever system is chosen are to provide the walnut trees with a uniform amount of water and nutrients through the growing season at the acceptable cost, to provide for frost and pest control without significant environmental damage, and to provide the necessary space to efficiently operate equipment for ground cover maintenance and nut collection.

On a deep, well-drained site suited for acceptable growth of eastern black walnut, the orchard management system should provide many of the following benefits through the growing cycle: a) provide a cover to decrease soil erosion and nutrient leaching below the root zone, b) keep soils cool to delay spring budburst and reduce damage by late killing frosts, c) allow air movement through the orchard to minimize frost pockets, d) remove excess soil moisture that has accumulated during the dormant season, e) reduce dispersal of airborne disease spores that affect walnut leaves, f) minimal competition for soil moisture and nutrients during the growing season, g) improve soil organic matter and nutrient cycling, and h) facilitate mechanical harvesting of nuts in the fall.

The ideal orchard management system provides an effective ground cover during the dormant season to minimize soil erosion and delay walnut budburst and flowering, abundant spring growth to remove excess soil moisture to enhance walnut root growth and increase soil organic matter when incorporated, sufficient root growth to firm the soil for operating equipment when spraying or performing other cultural activities, minimal competition for soil nutrients and water during the summer when nuts are developing, and minimal above ground biomass in the fall to impede mechanical harvesting of fallen nuts. Mechanical harvesting is likely to use equipment to sweep fallen nuts into windrows followed by some type of cleaner to separate the nuts from leaves, twigs, and other trash raked into the windrows. As with most things, no one ideal orchard management system meeting all the above criteria exists; however, systems do exist that meet many of the above criteria.

Orchard floor management systems can include 1) complete cultivation, 2) complete chemical weed control, 3) sod culture, and 4) sod culture with strip weed control. The following section describes each management system and some advantages and disadvantages of each system.

Complete cultivation. This system involves periodic cultivation of the entire orchard floor from late spring through nut harvesting. The major advantage is minimal competition from other plants for soil moisture and nutrients during the growing season. Periodic tillage also reduces surface evaporation of soil moisture by disrupting the capillary rise of soil moisture to the surface. However, it should be noted that potential evaporation rates from bare ground, even when periodically tilled, can still be almost as great as from orchard floors covered with lowing growing vegetation. A major disadvantage with complete cultivation is that the shallow feeder roots in the upper soil layers are repeatedly cut or injured. Another major disadvantage is that complete cultivation should be limited to level ground unless other conservation practices are used to minimize soil erosion.

Complete cultivation is usually the most expensive management system because it must be periodically repeated during the year, requires more time, and uses larger tractors than other systems. Complete cultivation normally requires square planting designs to facilitate cultivation in both directions where wide equipment can limit the number of walnut trees planted per acre and reduce selection gains from thinning. The larger tractors needed for cultivation can also lead to more soil compaction and reduce water infiltration. In addition, during periods of heavy rainfall, cultivation on a timely basis may not always be possible. This can be especially critical in the fall when the soil surface needs to be tilled and leveled to facilitate sweeping fallen nuts into rows for mechanical harvesting. A cultivated orchard may require harrowing and floating to make it level along with rolling with a cultipacker or other equipment to firm the soil surface.

A modification of the complete cultivation system adaptable to eastern black walnut orchards is the late fall planting of cool-season annuals to establish a ground cover during the winter. Diseased walnut leaves can be incorporated during cultivation or covered by the ground cover to restrict dispersal of fungal spores in the spring. Establishing a winter ground cover has the added advantage that it can be incorporated the following spring to improve soil tilth and water infiltration rates. Use of annuals legumes such as hairy vetch or crimson clover have the added advantage that they are efficient nitrogen fixing plants that can be expected to provide as much at 100 pounds of nitrogen per acre when incorporated as a green manure crop. If the legume top growth is not harvested, it could provide up to nearly half the annual estimated 200 pounds of nitrogen per acre need to sustainable nut production in walnut orchards. Most winter annuals can be seeded in the fall as part of an operation to prepare the orchard floor for mechanical harvesting of the fallen nuts. It is generally recommended that winter legumes be planted about one month prior to the first frost date. Winter annuals such as hairy vetch, subterraneum clover, and crimson clover are good choices because they do not produce abundant height growth until the following spring.

The use of climbing winter annuals like hairy vetch could significantly reduce the number of cultivations needed the following year. In the spring, hairy vetch will climb, overtop, and kill most weeds in the spring before it produces seed and dies. If not incorporated, the dead hairy vetch vines form a dense mulch across the planting. The mulch layer effectively shades the soil preventing new weed seeds from germinating and reduces the amount of soil moisture normally lost through evaporation from bare ground. Because hairy vetch is an efficient nitrogen fixing legume, the summer decomposition of the roots and mulch slowly provides a rich source of nitrogen and other nutrients to the walnut trees. In some areas, a foliar disease kills the vines before seed pods are formed. In these areas, the hairy vetch mulch needs to be incorporated by cultivation in late summer to prepare the seedbed for reseeding and mechanical harvesting of fallen nuts.

Complete chemical control. This system uses various chemicals to control weeds during the growing season and harvesting period rather than cultivation. This system causes less compaction because it can use small tractors and other equipment with floatation tires to spread the weight of equipment over a larger surface than equipment for complete cultivation. Under complete chemical control, walnut roots are left undisturbed and can grow into the more fertile upper zone of the soil. Major disadvantages include the limited number of herbicides currently registered for use in walnut orchards, their expense, and their persistence in the environment. In addition, during periods of heavy rainfall, it is not always possible to apply herbicides when weeds are at their most susceptible life stage. Surface runoff can also be a problem in orchards where weeds are continually controlled with herbicides, especially if the orchard is also irrigated with sprinklers.

With complete chemical control it may be advisable to establish a cool-season annual in the fall to protect the site from soil erosion during the winter. In addition, the ground cover would hold or recycle nutrients in the upper soil layers especially leachable nutrients like nitrate nitrogen. The advantages of using annual legumes over annual grasses for complete chemical control are not as great as when the ground cover can be incorporated. For annual legumes more than three-fourth of the fixed nitrogen is found in the above ground parts. After herbicide application in the spring it is unclear how much of this nitrogen will enter the soil and how much will be lost as volatile ammonia during decomposition. The dead vegetation from either annual legumes or grasses following herbicide application would effectively mulch the soil surface and should reduce the emergence of other weeds that may not be more susceptible to herbicides.

Sod culture. Under this system, the orchard floor is maintained with existing weeds or a planted cover crop. The covercrop maybe planted grasses, legumes, or weeds. Sod culture offers several advantages over both complete cultivation and complete chemical control. The permanent cover allows nearly year-long access to the orchard for cultural practices such as pruning, thinning, and spraying. Because sods can be maintained with small tractors and inexpensive mowers, sod culture is less costly than discing or use of herbicides for weed control. The system is well designed for use on rolling terrain typical of cover sites where some of the best walnut growth occurs. Rolling terrain provides for better air movement through the walnut orchard thus reducing the incidence of frost damage to the new spring growth and developing flowers.

The major disadvantages to sod culture are that additional water and nutrients that must be applied to maintain both the walnut trees and the covercrop. This is especially true if the covercrop is harvested as in alley cropping situations. Although the information is limited, we know some perennial ground covers like tall fescue or smooth bromegrass produce toxic exudates that can slow the growth of walnut. In addition, many of the grasses are bunch grasses and do not form a tight sod, thus making it more difficult to sweep nuts into windrows for mechanical harvesting of fall nuts. Conversely, we also know that black walnut produces toxic root exudates that could limit the growth of groundcovers. Most plants have been shown to be sensitive to juglone at high concentrations in laboratory studies. High juglone concentrations could be expected to occur during summer dry periods under conditions of low available soil moisture. Evidence suggests that there are a limited number of soil microorganisms capable of breaking down juglone. Orchard soils with good aeration and high levels of decomposing plant residues favor growth of these microorganisms; thus, juglone should not be a problem when selecting groundcovers for nut orchards on deep, well drained walnut sites.

A promising sod culture system current being tried in the central part of the eastern black walnut range is a mixture of Kentucky bluegrass and Dutch white clover. Bluegrass can be found invading many plantings and can be expected to form a thick sod from which fallen nuts can be sweep into windrows. Dutch white clover is also a low creeping legume that spreads by stolons which grow along the surface of the soil. White clover is an excellent nitrogen fixing legume and during decomposition of roots and aerial parts will release nitrogen to the grass and walnut trees. Estimates of nitrogen-fixing ability of white clover in grass pastures are reported as high as 225 pounds of nitrogen per acre. Both Kentucky bluegrass and Dutch white clover flower early in the spring and if left undisturbed should remain relatively dormant through the summer minimizing competition with the walnut trees for moisture and nutrients. Because the growing points of both species are close to the ground, a bluegrass-white clover sod can be mowed close to the ground with a flail mower in the fall. Flail mowers are more efficient than rotary mowers for scalping the groundcover close to the ground to prepare the orchard for sweeping mechanical harvesting of fallen nuts.

Most perennial legumes such as birdsfoot trefoil, red clover, alsike clover, and alfalfa lack shade-tolerance and are poorly adapted to mowing with flail mowers. In addition, they may produce too much above ground biomass on the orchard floor if fallen nuts are to be sweep into windrows for mechanical harvestings. Warm-season legumes like serecia lespedeza and perennial soybeans should not be used because their most vigorous period of growth is during the summer when soil moisture is likely to be limited.

Sod culture with strip weed control. This orchard management system combines sod culture between the tree rows with use of a weed-free zone within tree rows. The weed-free zone is usually a 6 to 8 foot wide strip in the tree row maintained with herbicides. Sod culture with strip weed control takes advantage of many of the benefits of the three previous systems. Sod culture with strip weed control is adaptable to rolling terrain if tree rows are planted on the contour. Sod culture with strip weed control is easily adapted as an agroforestry practice for orchard establishment. In the past, winter wheat, soybeans, and sorghum have been successfully grown between the rows of trees planted 22.5 to 40 feet apart. With the latter spacing, agricultural crops have been grown between the tree rows for six to twelve years before plantings were converted to a permanent sod. Strip weed control is usually done in the spring or the fall using a combination of pre-emergent and post-emergent herbicides. Recent studies have shown that herbicide applications in combination with liquid fertilizers will increase nut production while similar applications in the spring are no more effective than using herbicide mixtures only.

Sod culture with strip weed control may allow walnut growers to use grasses such as tall fescue and smooth bromegrass. Grasses sods have been shown to significantly reduce elongation of tree roots in response to toxic chemicals and/or low nitrate nitrogen availability. Several demonstration plantings have shown that periodic cultivation to remove a tall fescue sod between alternate rows of walnut trees was as effective as complete removal of the tall fescue sod to rejuvenate tree growth. Strip weed control using herbicides within the tree rows maybe equally effective, but remains to be tested. It is important to emphasis that most studies show walnut trees in grass sods grow slower than trees with sods from native plant populations (weeds). Conversely, trees in sods of planted legumes frequently grow faster than trees with sods with a mix of native grasses and forbs.

Several more environmentally friendly alternatives using herbicides for strip weed control exist; however, their effectiveness in walnut orchards has not been evaluated. Cultivators with rotating tines have been developed that mount to the side of a tractor for cultivating around trees. With these cultivators, the weed free zone is rather narrow and they are not very effective on weeds more than 6 to 10" tall. Mulching with a 3 to 4" deep layer of compost, yard wastes, or wood chips will effectively suppress most weeds. These materials can provide a slow, steady supply of nutrients into the root zone under the trees. The major disadvantages to mulching are the amounts of labor required to apply and maintain the strips and fallen nuts cannot be harvested by sweeping into windrows. Recently, woven plastic or polypropylene fabrics have been developed that have functional life expectancies of 10 years or more. Although rainfall and liquid fertilizers can penetrate these woven fabrics, they also act as a mulch reducing surface evaporation of limited soil moisture during the growing season. The major disadvantage to woven fabrics is the high initial cost and lack of mechanical equipment for installing fabric in established nut orchards.

Black Walnut Nutrition

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Abstract: Information on soil and leaf nutrient concentrations for black walnut are of value only when they are properly sampled, accurately analyzed, and the results correctly interpreted. Guidelines for interpreting soil and leaf analyses and leaf symptoms are presented along with recommendations for correcting nutrient deficiencies or the imbalance of one or more nutrients.

The importance of nutrition in old field plantings of nut bearing trees is well recognized. Black walnut is found naturally on deep, moist, well-drained, and aerated soils that have good structure and are near neutral in pH. However, many walnut plantings are established in residual soils that may be eroded and highly leached. Restoring these soils to the productivity capacity required by black walnut could involve a large investment of time and nutrient management. Excess or deficiency of nutrients can cause an imbalance, which can result in abnormal growth and low nut production. Ideally, the soil's optimum nutrient-balance should be adjusted prior to planting. Broadcast nutrient applications without mixing in existing plantings can be effective; but, depending on the nutrient's mobility, it may require more time for the beneficial effects of some to be realized than for others.

The elements essential for normal growth of walnuts and other green plants have been categorized as major elements, which are required in large amounts, and minor elements, which are required in small amounts. Black walnut requires large amounts of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), and smaller amounts of sulfur (S), iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu), and molybdenum (Mo).These elements are considered essential because their absence can be demonstrated to cause injury, abnormal development, or death to the plant.

DIAGNOSING NUTRIENT NEEDS

One objective for looking at nutrient needs diagnostically may be to determine why a tree or stand exhibits poor growth and/or foliage or other organ abnormalities such as discoloration or unusual development. Another may be to determine the occurrence of nutrient deficiencies that inhibit nut production. Preventing nutrient disorders is easier than correcting them. It may take several years to correct deficiencies or imbalances. During this time losses in growth and yield continue.

Nutrient needs may be estimated (1) by using leaf appearance to identify nutrient deficiency symptoms, (2) by comparative analysis using both soil and leaf analyses, (3) by soil analysis, and (4) by leaf analysis. The appearance of the leaves can sometimes provide the first clue to which nutrient or nutrients are deficient. Nutrient deficiency symptoms for black walnut have been documented (Hacskaylo et al. 1969). They used color photographs to show leaf deficiency symptoms of N, P, K, Ca, Mg, S, Fe, and Mn. A detailed description of each deficiency symptom is provided in Table 1. Although nutrient deficiencies may manifest themselves in quality characteristics of the leaf, symptoms for a deficiency of one or more elements may be similar to the deficiency symptom of another element. For that reason, leaf symptoms for some nutrient elements such as B, Cu, and Zn have not been included in Table 1. Also, some deficiency symptoms can result from toxicity or nutrient imbalances rather than insufficiency in the soil. The grower should be careful not to mistake injury caused by equipment, insects, pathogenic diseases, herbicides, and pesticides for a deficiency symptom. These agents may produce symptoms that are almost identical to those of malnutrition. Visual deficiency symptoms should be confirmed by leaf mineral analysis.

The comprehensive approach to diagnosing nutrient needs is to analyze leaf samples from trees or a stand that exhibit satisfactory growth and nut yields and corresponding soil samples from the soils in which the trees are growing. The levels of nutrients in the samples are then used as standards to compare other trees or stands of trees and soils. Comparative analyses serve to provide a range of values. The analysis is of the most value when the tree's nutritional differences may be related to some aspect of soil. However the greatest unreliability of comparative values may be expected when values are extrapolated from one growing location to another or from a tree or stand at one stage of development to another of a different age or stage of development.

Leaf Analysis

The leaf is very sensitive to changes in the plant's nutrient supply. The leaf is the food producing organ of the plant and a place of intense metabolic activity. The reliability of the results obtained from leaf analysis depends to a large degree on how and when samples were collected. The concentration of leaf nutrients varies with the time of the year (Table 2), the position of the leaf on the shoot, and with the position of the leaflets on the leaf. Collections should be made between mid-June to mid-July. However, some authors suggest collecting leaf samples as late as early August (Phares and Finn 1971, McHargue and Ray 1932). Concentrations of N and P decrease over the growing season while Ca increases. Calcium concentration decreases from basal to apical leaves on a shoot and from basal to apical leaflets on the leaf. Therefore, the sampling procedure should be standardized. For example, select one or two pair of leaflets from the mid-portion of mature black walnut leaves for the sample rather than from the apical or basal end only. Also, select a date to annually sample the same trees, leaves from the same branches, and position on the branches.

Leaflets should be placed in paper bag. If plastic bags are used, precautions should be taken to prevent leaves from molding. Select leaves from branches around the upper half of the crown. Leaves that are dirty or have been injured by insects, disease or other factors should be discarded. Collections should be delayed several days after heavy rains because some of the nutrients may be dissolved in the rainwater. A sample of 10 to 20 leaves from each tree should be adequate for most analyses. After leaves have air-dried for several days, they may be sent to a plant test laboratory for analysis. When equipment is available, leaves can be oven-dried and ground before sending them to the laboratory for analysis.

Interpreting Leaf Analysis

The literature on black walnut fertilizations trials was recently summarized (Ponder 1997). He concluded that the lack of long-term fertilization studies affect efforts to satisfactory diagnose and prescribe adequate fertilizer recommendations. Also, many of the published results that showed a response to fertilization did not include data on soil and leaf analyses (Geyer et al. 1979, Stringer and Wittwer 1985, Jones et al. 1993). Thus, while there may have been an increase in the supply of a limiting nutrient that resulted in the growth and/or nut yield response, the impact of the nutrient application on soil and leaf nutrient concentrations for trees in the studies are not known. Leaf analyses are usually able to detect these kinds of dilution effects.

The key factor in the successful use of leaf analysis to detect nutrient deficiencies is having reliable information on leaf composition values that are associated with deficiency and optimum growth and yield. Such information is very scarce. However, limited, some information is available on black walnut leaf composition (McHargue and Ray 1932, Phares and Finn 1971, Ponder 1976, Maeglin et al. 1977).

Phares and Finn (1971) were the first authors to compile a list of tentative critical black walnut leaf composition values based on their research and other published reports (Table 3). Phares and Finn (1971) used good growth as the primary criterion for selecting the critical nutrient levels, but subsequent research has shown that these critical levels are applicable for increasing nut yields (Ponder et al. In press).

Fertilization application rates to correct deficiencies based on leaf symptoms and leaf analyses are not presented. Deficiencies should be corrected using recommendations based on soil analyses.

Soil Analysis

Attempts to relate tree growth and nut production to soil-nutrient analyses has had limited value. Tree performance is neither consistently nor highly correlated with soil analyses. Similarly, soil analysis is not highly correlated with leaf analyses. There are two major reasons for this. One is the difficulty in determining meaningful values for availability of a particular nutrient to the tree; thus any method of extracting an element from the soil is arbitrary in comparison to what actually happens in the root environment during nutrient uptake. Most chemical extractions will give different values, depending on the soil properties.

The second reason is the variability in the root distribution of a given tree. It can vary considerably with soil type. However, regardless of the limitations of soil analyses, they are necessary to fully understand the nutrient status of the tree. Tentative soil nutrient standards are presented in Table 4. Knowledge of soil nutrient levels can be essential in correcting imbalances and heading off future problems. The upper foot of soil should be sampled in a grid or other systematic pattern so that the origin of the sample can be identified. By keeping the 0 to 6 inch depth separated from the 7 to 12 inch depth for the analysis, the manager can look at the vertical distribution or movement of nutrients, especially applied P and lime. If trees are on the site, both soil and leaf samples should be from the same area. Also, consistently collect samples from the same trees and from the same local spot on the ground. This will reduce sample variation and increase the reliability of the data from the analysis. Based on test results, recommended nutrient applications can then be made in the tested area.

pH

Maintaining the proper pH is important in any fertilization program. The effects of soil pH on plant growth are indirect, very complex, and may vary with soil types. Alteration of plant growth occurs because others factors are changed in the soil as pH changes (Thomson and McComb 1962). For example, ammonium nitrate applications can decrease soil pH resulting in a decrease in Mg, Ca, K, and P concentrations in the soil. The decrease occurs during leaching as those of hydrogen and aluminum replace ions of these nutrients on the soil particles. Soil pH has a direct effect on the soil's microbial activity and this activity is important in the breakdown of organic matter and the subsequent release of N and P.

The pH should be maintained between 6.0 and 7.2. The pH should be corrected during site preparation and tested periodically to detect any change in pH. Lime is usually added to raise the pH of most soils to the desired level. The amended pH can be expected to last from 3 to 5 years.

Continued applications of acid forming fertilizers such as ammonium nitrate can result in nutrient imbalances. However, maintaining high soil pH (above 7.2) can reduce the availability of zinc. Nitrogen applied with P often increases the concentration of P in the plant, but the increase varies with the type of N as well as with soil conditions. Although the imbalance of nutrients in the soil is somewhat understood, the impact of nutrient imbalance on the growth and nut production of black walnut is not.

Maximum P availability to plants is realized between a pH of 6.2 to 6.7. The movement of P in the soil is relatively slow compared to other nutrient elements. Consequently, both growth and nut yield responses may require several years. For example, improvements in the amount of growth was noticeable in young trees during the first summer following treatment, but mature trees were much slower in showing a response (Seer 1960). Some of the difference in response time could also be attributed to physiological differences associated with the age of the trees. Seer (1960) reported that English walnut nut yield and kernel percentages were significantly improved by an application of superphosphate. The response from a single application of P can last several years. Also, depending on the soil P levels, infection levels of the beneficial mycorrhizal forming fungi may be affected. It appears that high soil nutrient levels, especially P, suppress mycorrhizal formation. These beneficial fungi have the ability to inhabit roots and improve P nutrition of the plant. Unless soil P levels are excessive, normal mycorrhizal development should compliment root uptake of P (Ponder 1984).

Cation Exchange Capacity (CEC)
The balance of cations [H, K, Ca, Mg, and sodium (Na)] can be important for adequate nutrition. For soil with a CEC of 5 to 10 meq/100 g soil, the following percentage base saturations are suggested: 65 to 75 for Ca, 10 to 15 for Mg, 2.5 to 7 for K, and 0 to 5 for H and Na. Despite the interrelationships between K, Ca, and Mg ratios, less than optimum for these elements probably will not seriously affect yields unless the ratio of one of these elements to another is very wide (Mills and Jones 1996). For example, Ca deficiency is not likely unless the ratio of Ca:Mg is less than 2:1 and Mg deficiency is not likely until the ratio is greater than 20:1.

Lime when applied as dolomitic lime also supplies Mg. Calcite lime does not supply Mg. Although the effects of K, Ca, and Mg on other elements are less than the effects on each other, the concentration of these elements in the soil and leaf are affected by and have an effect on other elements.

Recommendations given by the testing laboratory will explain the fertilizer rate to use to raise the soil nutrient level to the acceptable range. The laboratory may also explain which fertilizer to use.

TIMING NUTRIENT APPLICATIONS

Fertilizer applications to correct deficiencies should be made when black walnut can make the most efficient use of the nutrients. The most inefficient time to apply N is in the winter when roots are less active and least able to absorb it. Losses from leaching and dinitrification can also occur at this time. Phosphorus is very immobile. It requires several years to move short distances in the soil profile, and can be applied at the manager's convenience. When convenient, shallow disking the soil following P fertilization can decrease the time it takes for P to become available for plant uptake. Lime can also be applied at any time. Although not tested as a recommended practice, black walnut should benefit from split applications of fertilizer. Important nutritive sensitive events are occurring in black walnut throughout the growing season. Flower initiations occurs in late summer; diameter growth, fruiting, and fruit maturation begins in the spring and continues over much of the summer. Jones et al. (1993) reported that late summer fertilization increased nut production by 32% over spring fertilized trees and by 34% over unfertilized trees. Split applications of N are recommended on sandy soil to reduce leaching losses.

Black walnut nut yields in response to early spring fertilizations should not be expected to be evident until the second year after fertilization; however, leaf N concentrations will show a response in the current year's foliage (Ponder et al. In press). Careful annual testing of soil and leaves will be the best guide to determining how often to apply fertilizers.

SOIL and PLANT ANALYSIS LABORATORY

Most leading state universities that have agriculture programs maintain and operate soil and plant testing laboratories. However, many of them probably do not make fertilizer recommendations for black walnut, but they do make recommendations for growing non-irrigated corn. The recommendation for non-irrigated corn should be adequate for supplying the nutrient needs for black walnut. The Soil and Plant Analysis Laboratory in Madison (University of Wisconsin, Soil and Plant Testing Laboratory, 5711 Mineral Point Road, Madison, WI 53705, phone 606/262-4364) can analyze soil and plant samples and make recommendations for walnut based on the soil's pH and their organic matter and nutrient content (Parker et al.1992). Request that the testing laboratory provide both test results and recommendations in units that you understand (ie., lbs/ac not ppm). The form containing the results and recommendations will usually have an explanation for the tests and conversion factors that can be used to make appropriate unit changes as part of the interpretation. Visit with personnel at your Natural Resources Conservation Service office, County Extension office, District Forester office or local University Extension Forester's office for help in locating a testing laboratory or any other help and suggestions for your trees.

REFERENCES

Geyer, W.A., G.G. Naughton, and N.F. Rogers. 1979. Black walnut (Juglans nigra L.) response to release and fertilization on strip mined lands in southeastern Kansas. Trans. Kans. Acad. Sci. 82:178 -187.

Hacskaylo, J., R.F. Finn, and J.P. Vimmerstedt. 1960. Deficiency symptoms of some forest trees. Ohio Agr. Res. And Develop. Center Res. Bull. 1015, 68 p.

Jones, J.E., J. Haines, H.E. Garrett, and E.F. Lowenstein. 1993. Genetic selection and fertilization provide increased nut production under walnut-agroforestry management. p. 39-42. In Proc. Third North American agroforestry conf.

Maeglin, R.R., H. Hallock, F. Freese, and K.A. McDonald. 1977. Effect of nitrogen fertilization on black walnut growth, low quality, and wood anatomy. USDA Forest Service Res. Pap. FPL-294. 13 p.

McHargue, J.S. and W.R. Ray. 1932. Mineral and nitrogen content of the leaves of some forest trees at different times in the growing season. Bot. Gaz. 94:381-393.

Mills, H.A. and J.B. Jones. 1996. Plant Analysis Handbook II. MicroMacro Publishing, Inc., Athens, GA. 442 p.

Parker, D., J. Bockheim, and D. Meyer. 1992. Soil and site selection. Wisconsin Walnut Council, act Sheet No. 68, Walnut Tip.

Phares, R.E. and R.F. Finn. 1971. Using foliage analysis to help diagnose nutrient deficiencies in black walnut. North. Nut. Grow. Assoc. Annu. Rep. 62:98-104.

Ponder, F., Jr. 1976. Fertilization increase nut, but not wood, production of pole-size black walnut. North. Nut Grow. Annu. Rep. 67:60-63.

Ponder, F. Jr., R.E. Phares, and R.C. Schlesinger. 1979. Seasonal variation in foliar composition of black walnut trees. Commun. Soil Sci. and Plant Anal. 10:1513-1521.

Ponder, F., Jr., J.E. Jones, and J. Haines. (In press). Annual applications of N, P, and K for four years moderately increase black walnut production. HortScience.

Ponder, F., Jr. 1984. Growth and mycorrhizal development of potted white sah and black walnut fertilized by two methods. Can. J. Bot. 62:509-512.

Seer, E.F. 1960. Response of Persian walnut to superphosphate. American Soc. Hort. Soc. 77:301-307.

Stringer, J.W. and R.F. Wittwer. 1985. Release and fertilization of black walnut in natural stands. pp. 62-67. In: J.O. Dawson and K.A. Majerus (eds.). Proc. Fifth Cent. Hardwoods For. Conf.,Urbana-Champaign, IL.

Thomson, G.W. and A.L. McComb. 1962. Growth of plantation black walnut in relation to pH and certain chemical factors of the soil. For. Sci. 8:322-333.

Table 1. General description of deficiency symptoms for various nutrients in black walnut leaves.[1]

Nutrient	Most apparent deficiency symptoms
N	Leaflets and rachis small. Leaflets yellow to yellowish-green, veins yellow. Leaflets have a rough, crinkly appearance. Number of leaflets reduced.
P	Leaflets and rachis small. Yellowish rachis. Chlorotic areas on the leaflets between veins. Lateral leaflets exhibit bronzing. Number of leaflets reduced.
K	Leaflets light yellowish green with marginal yellowing, especially at tips. Rachis yellow-green to yellow. Leaves small. Number of leaflets reduced.
Ca	Leaves very small. Leaflets have chlorotic areas and patches of light green to yellow. Terminal leaflet has tip burn. In extreme case, leaf loses most green coloring and appears bleached. Number of leaflets reduced.
Mg	Leaf size about normal. Some small chlorotic areas. Leaflets yellow-green to light green. Veins remain green. Number of leaflets normal.
S	Leaves are small. Leaflets pale green to almost bleached white. Veins near base of leaflet darker green than other leaflet tissue. Rachis is green to purple. Number of leaflets normal.
Fe	Similar to sulfur except less reduction in leaflet size and veins remain green especially adjacent to the mid-vein. Leaflet surface smooth. Number of leaflets normal.
Mn	Leaf size about normal. Rachis is brownish, basal leaflets show bleaching along margins, and overall leaf color is yellow-green. Number of leaflets normal.

[1]Hacskaylo et al. 1969.

Table 2. Mean concentrations of N, P, K, Ca, and Mg in leaves from young (first sampled at age eight) black walnut trees at different times of the growing season for two years.[1]

Date Sampled	Nutrient element				
	N	P	K	Ca	Mg
	Percent				
First year					
June 11	3.11	0.32	1.07	1.96	0.51
July 6	2.91	0.25	0.97	1.97	0.42
August 11	2.84	0.24	1.02	2.36	0.44
Second year					
June 11	3.52	0.25	0.98	1.28	0.37
July 6	3.02	0.20	0.80	1.61	0.36
August 11	2.73	0.21	0.83	2.15	0.41

[1]Ponder et al. 1979.

Table 3. Tentative leaf composition standards and reported leaf composition levels for black walnut.

Nutrient	Phares & Finn[1]	McHargue and Roy[2]	Mills and Jones[3]
	Percent		
Nitrogen	2.00 - 2.60	2.18	2.47 - 2.98
Phosphorus	0.10 - 0.25	0.32	0.16 - 0.24
Potassium	0.75 - 1.30	2.45	1.32 - 1.47
Calcium	0.50 - 1.10	2.68	1.90 - 2.01
Magnesium	0.15 - 0.45	0.47	0.51 - 0.64
Sulfur	0.05 - 0.25	0.05	0.15 - 0.16
	Parts per million		
Manganese	30 - 80	110	207 - 274
Iron	40 - 100	78	69 - 129
Zinc	15 - 50	26	33 - 55
Boron	20 - 50	--	66 - 81
Copper	5 - 10	11	10 - 12
Molybdenum	0.05 - 0.10	--	0.10 - 0.30

[1]Phares and Finn 1971, sampled in mid-August.
[2]McHargue and Ray 1937, sampled in August.
[3]Mills and Jones 1996, sampled in summer.

Table 4. Tentative soil range for pH, organic matter, N, P, K, Ca, and Mg levels for suitable black walnut sites.[1]

Analysis								
pH	Organic matter	N	P	K	Ca		Mg	
	(%)	(%)	lbs/a					
6.5-7.2	2.0-3.5	0.25-0.3	60-80	225-275	2000-3000[2]	3000-4000[3]	250-500[2]	375-600[3]

[1]Parker et al. 1992.
[2]Sandy soil
[3]Silty soil

Insects Pests Of Black Walunt

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Black walnut, Juglans nigra L., is an indigenous tree species that grows over a large portion of the United States east of the 100th meridian. It is a component of many of the eastern forest types but is seldom abundant. It occurs as a minor species in a few forest types and is generally found scattered among other trees. Pure stands are rare and usually found on the edge of the forest (Fowells 1965). In its native habitat, black walnut has few important insect enemies. The establishment and management of black walnut plantations, especially in the Midwest, have increased in recent years. Will the plantation landscape change the dynamics of insect herbivore - black walnut interaction? If so, what does this mean for the resource manager or land owner?

According to Marshall (1989), the reference book Insects of Eastern Forests (1985) lists sixty-five species of insects affecting the genus Juglans and black walnut (Marshall 1989). Kearby (1975) collected 62 species of insects associated with black walnut plantations in Missouri, and Nixon and McPherson (1977) listed approximately 300 species from plantations in southern Illinois. Many species of insects are associated with black walnut; however, few are pests of importance.

Marshall (1989) discussed the importance of insects affecting the growth and quality of black walnut trees. He presented information on numerous species of insects but suggested that relatively few should be of concern to black walnut growers. Among those that cause concern are the following: walnut shoot moth (Acrobasis demotella Grote), ambrosia beetle (Xylosandrus germanus (Blandford)) and periodical cicada (Magicicada spp.) because of their impact on wood quality; the walnut shoot moth, walnut caterpillar (Datana integerrima Grote & Robinson), fall webworm (Hyphantria cunea (Drury)), oystershell scale (Lepidosaphes ulmi (L.)) and ambrosia beetle because of their impact on tree growth. The black walnut curculio, Conotrachelus retentus (Say), an insect which impacts nut production in black walnut plantations (Linit and Necibi 1995) should be added to this list.

The propagation of black walnut outside the forest, its evolutionary home, changes the dynamics of insect-plant interactions. Establishment of a black walnut plantation results in a concentration of plant resources and increased plant apparency. In addition, plantation management practices may affect the survivorship of insect herbivores and their natural enemies, especially those which overwinter in the soil. How insect herbivores react to this new landscape will depend upon the interaction of the insect life history and management decisions made by the land owner. Below, four types of insect herbivores that feed on black walnut; a nut feeder, a defoliator, a shoot borer, and a sucking insect are examined. Aspects of their biology and plantation management decisions which may influence their success in a plantation environment are discussed. Control recommendations for several insect pests of black walnut are presented in a Purdue University Cooperative Extension Publication appended to this article.

The **black walnut curculio** develops in the nuts of black walnut and butternut. Nuts are produced in abundance on an irregular basis. The female curculio deposits an egg within a developing nut. The larva hatches then feeds within the nut causing it to drop prematurely (Blair and Kearby 1979). The pupal stage and the overwintering adult stage occur within the litter layer or soil. The abundance of the curculio is determined by the availability of nuts during the previous year (Linit and Necibi 1995). This relationship can be expected to hold as new walnut varieties are developed to increase the nut bearing capacity of the tree. Growers are not likely to experience outbreaks of the curculio but as nuts become more abundant in black walnut plantations the abundance of the curculio is likely to increase. Mowing or harvesting of ground vegetation within the plantation may be disruptive to the curculio life cycle and may prove to be a valuable pest management tactic (Linit and Necibi 1995).

The **walnut caterpillar** is the most destructive leaf feeding insect that occurs on black walnut. The female deposits a mass of eggs on the underside of leaves, often along forest margins or in forest openings, or on open grown trees such as ornamentals or trees in plantings (Farris and Appleby 1979). The larvae feed on leaves of several species in the Juglandaceae including walnut, butternut, pecan, and various species of hickory. If leaves within a tree become scarce the larvae will scatter in all directions in search of a new host. In a diverse plant habitat numerous non-host plants exist and larvae may have difficulty locating a suitable host. Larvae searching for additional foliage in a black walnut plantation need only find the next tree. The walnut caterpillar has many characteristics of an eruptive species, thus, occasional outbreaks should be expected. Walnut caterpillars pupate in the soil during late summer. Therefore, manipulation of ground vegetation may provide opportunities for management of this defoliator.

The **walnut shoot moth** is the most destructive shoot borer on black walnut. Females deposit single eggs on the undersides of walnut, hickory or pecan leaves in early summer. The young larva feeds on the lower epidermis of the leaves on which they hatch. In late summer, the larva constructs a hibernacula, located at the base of terminal bud or lateral buds, in which to overwinter. The larva emerges from the hibernacula at bud swell and feeds on the expanding bud. The larva bores into the elongating shoot and tunnels through the pith, destroying the shoot. The mature larva leaves the shoot and pupates in the soil (Kearby 1979, Martinat and Wilson 1979). Kearby (1979) suggested that total shoot loss in a black walnut plantation due to the shoot moth may be only 1 to 5 percent a year. While the annual incidence may remain low, deformity due to a shoot dieback may permanently reduce the value of the tree.

Like the walnut shoot moth, the **ambrosia beetle** can affect the growth and form of young black walnut trees and can also affect log quality. The beetle creates galleries within the wood of infested trees. During gallery construction, the beetle introduces a fungus that will stain the wood. Ambrosia beetle attacks on seedling or sapling age trees can result in form damage. If the terminal leader dies back, a new terminal shoot develops causing a sweep or crook in the future log. If killed back to the root collar, these young trees may produce multiple sprouts. Weber and McPherson (1984) found that the ambrosia beetle preferentially attacks slow growing seedlings and saplings and may not attack larger trees. They also reported that the impact of attack on young trees may be minimal because the trees have time to recover and produce quality logs prior to harvest age. Chemical control of the ambrosia beetle is not practical because the insect spends most of its life within the tree protected from chemical sprays. Weber (1982) recommended the use of cultural practices, such as the selection of appropriate planting sites and weed control, to maintain vigorous growth of black walnut seedlings and saplings as a deterrent to ambrosia beetle attack.

Piercing-sucking insects, such as scale insects and aphids, insert their mouthparts into the vascular tissue of twigs and feed on the vascular fluids. The oystershell scale is one such insect. Eggs are deposited and overwinter under the adult female scale. First instar larvae, called crawlers, disperse to new host trees and attach themselves to a twig on a suitable host. The scale has a wide host range including many fruit and hardwood trees grown in forests or as ornamentals. Heavy infestation can result in branch dieback. Many piercing-sucking insects have characteristics of eruptive species and occasional outbreaks should be expected.

The life history characteristics of an insect herbivore determine its ability to rapidly increase in abundance and thus its capacity to attain outbreak densities. The spatial and temporal occurrence of outbreaks is greatly influenced by biotic and abiotic factors such as parasitoids and predators, climatic conditions and resource availability (quantity) and quality. The establishment of black walnut plantations will influence a host tree - insect interactions. The implications for management of insects feeding on black walnut are not always obvious. Understanding the impact of resource concentration, through plantation establishment, on insect herbivores, and the biological interactions between insect life histories and plantation management practices should facilitate pest management decisions in a plantation landscape.

LITERATURE CITED

Blair, L.M. and W.H. Kearby. 1979. The black walnut curculio and its impact on nut production. In Walnut Insects and Diseases Workshop Proc.; June 13-14, 1984; Carbondale, IL, St. Paul, MN: N. Central Forest Exp. St., U.S. Dept. Agric., Forest Service: 51-54.

Farris, M.E. and J.E. Appleby. 1979. The walnut caterpillar, Datana intergerrima G & R. In Walnut Insects and Diseases Workshop Proc.; June 13-14, 1984; Carbondale, IL, St. Paul, MN: N. Central Forest Exp. St., U.S. Dept. Agric., Forest Service: 22-28.

Fowells, H.A. 1965. Silvics of forest trees of the United States. Agric. Handbook No. 271. Washington, D.C: U.S. Department of Agriculture, Forest Service. 762 p.

Kearby, W.H. 1975. Insects that affect the growth and form of black walnut in a multicrop system. 66th Ann. Rept. Of the Northern Nut Growers Assn. pp. 119-127.

Kearby, W.H. 1979. The life history of Acrobasis demotella and its role in seedling and sapling stem deformities in Missouri. In Walnut Insects and Diseases Workshop Proc.; June 13-14, 1984; Carbondale, IL, St. Paul, MN: N. Central Forest Exp. St., U.S. Dept. Agric., Forest Service: 55-57.

Linit, M.J. and S. Necibi. 1995. Black walnut curculio: patterns of nut damage in a plantation environment. Agroforestry Systems. 29:321-331.

Marshall, P.T. 1989. Insects that affect growth and quality of black walnut. pp. 193-202. Carbondale, IL: Proc. of the 4th Black Walnut Symposium.

Martinat, P.J. and L.F. Wilson. 1979. The life histories of Acrobasis juglandis and A. demotella on black walnut in Michigan. In Walnut Insects and Diseases Workshop Proc.; June 13-14, 1984; Carbondale, IL, St. Paul, MN: N. Central Forest Exp. St., U.S. Dept. Agric., Forest Service: 40-43.

Nixon, P.L. and J.E. McPherson. 1977. An annotated list of phytophagous insects collected on immature black walnut trees in southern Illinois. Great Lakes Entomol. 10:211-222.

Perrin, R.M. 1977. Pest management in multiple cropping systems. Agro-ecosys. 3:93. USDA. 1985. Insects of Eastern Forests. Forest Service Misc. Publ. No. 1426. Washington, D.C. 608 p.

Weber, B.C. 1982. Ambrosia beetles in your black walnut plantation how serious are they? USDA-forest Service, Gen. Tech. Rep. NC-74

Weber, B.C. and J.E. McPherson. 1984. Attack on black walnut trees by the ambrosia beetle Xylosandrus germanus (Coleoptera: Scolytidae). For. Sci. 30:864-870.

Managing Insect Pests of Nut Trees

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Insect and mite pests of nuts are best managed when sound Integrated Pest Management (IPM) principles are used. These include proper identification of the pest, selection of the appropriate management tactic and proper timing and placement of control measures. In this article, we provide information to help you implement this approach for pests of Pecans and Walnuts.

Monitoring plants for pests is critical for a successful IPM strategy. Plants can be inspected visually for pest presence and pest activity at least once every 2 weeks. Some pests such as codling moth and hickory shuckworms have traps available that can help you time your pesticide application. Several pests of these crops; such as mites, aphids, and scales can be controlled by conserving the natural enemies in your nut grove. This is best accomplished by reducing conventional pesticide use or by choosing a biorational material such as *Bacillus thuringiensis* to control caterpillars.

Do not pasture dairy animals or livestock in groves that have been treated with insecticide. Be sure to read the label and to follow all restrictions concerning Pre-Harvest Intervals (PHI), re-entry times, and maximum seasonal dosages. Some of the materials listed are Restricted Use Pesticides (RUP) and can only be used by licensed applicators.

WALNUT INSECTS		
Insect	**Treatment**	**Comments**
CODLING MOTH *Cydia pomonella* (L.)	Cultural Practices	Plant later blooming varieties when available.
Pinkish-white caterpillars (1" long) with brown heads feed in walnut husks. Feeding by first generation caterpillars on small nuts causes premature drop. Second generation feeding discolors nuts as stem end.	Sanitation	Remove and destroy fallen nuts and debris in fall.
	Monitoring	Place pheromone traps in trees in May. Make first insecticide application 7-10 days after first moths are caught. Repeat 10 days later. Repeat as before when first moths of second generation occur in July.
	Insecticides	Do not apply after husks open
	Bacillus thuringiensis OR	Many brands available. 0 day PHI.
	Ambush 25W at 12.8-25.6 oz. per acre. OR	Apply up to 102.4 oz per acre per season. RUP. 1 day PHI.
	Asana XL 9.6-19.2 oz. per acre.	Apply up to 38.8 oz per acre per season. RUP. 21 day PHI.

Walnut Insects (continued)		
INSECT	TREATMENT	COMMENTS
CODLING MOTH (cont.)	OR Diazinon 50W or 50WP at 6 lbs per acre, or Diazinon AG500 at 3 qts per acre.	Do not apply after husks open.
	Guthion 2S, or 2L at 6-8 pts per acre, or 35W at 4.25-5.68 lbs. per acre. OR	Up to 3 applications per year. RUP. 30 day PHI.
	Lorsban 4E at 4 pts per acre, or 50W at 4 lbs per acre. OR	Up to 3 applications per year. 14 day PHI.
	Pounce 3.2EC at 8-16 oz per acre. OR	Apply up to 64 oz per acre per season. RUP. 1 day PHI.
	Sevin XLR, or 4F at ½ qt per 100 gal or 80S at 2 lbs per acre. OR	General use insecticide. 0 day PHI.
	Supracide 2E 2 pts per 100 gal	Up to 3 applications per year. RUP. 7 day PHI.
WALNUT HUSK FLY *Rhagoletis completa* (Cresson)	Cultural practices	Plant later blooming varieties when available.
White maggots (3/8") feed in husk which can soften, turn black and stain nut meats. Nuts can shrivel during heavy infestation.	Sanitation	Remove and destroy fallen nuts and debris.
	Insecticides	Apply in late July and repeat in 2 weeks. Mix with Staley's bait. Write: A.E. Staley Mfg. Co., 2200 Eldorado St.., Decatur, IL 62525
	Ambush, Asana, Guthion, or Pounce. OR	Same as for coding moth.
	Malathion 57EC at ½ pt per gal.	0 day PHI.
WEEVILS, CURCULIO *Conotrachelus spp.*	Sanitation	Remove and destroy fallen nuts and debris in fall.
Reddish-brown snout nosed beetles (1/2") leave crescent shaped scars in husks when females drill holes and lay eggs. Creamy-white grubs feed in kernels. Two species are present in Indiana.	Insecticides	No insecticides are labeled at this time.

Walnut Insects (continued)		
INSECT	TREATMENT	COMMENTS
CATERPILLARS: Walnut Caterpillar *Datana integerrima (G & R)* Hairy reddish-brown caterpillars with fine yellow stripes running along body, which feed in groups and defoliate branches. One generation per year.	Monitoring Insecticides *Bacillus thuringiensis* OR Diazinon	Inspect trees for white egg masses on leaf undersides in July and for groups of caterpillars in late July and August. Spray when and where caterpillars are found. Do not apply after husks open. Many brands are available. Most effective when caterpillars are small. Same as for codling moth.
CATERPILLARS: Fall Webworm *Hyphantria cunea* (Drury) White haired caterpillars feed in webbed masses on branch tips and remove foliage. Two generations per year, one starting in mid-May, and the second in late July.	Monitoring Insecticides	Inspect trees in May and June for webs of the first generation on branch tips. Repeat in late July and August. Same as for walnut caterpillar.
APHIDS: Black margined, dusky veined walnut aphid, giant bark aphid, and walnut aphids. During heavy infestations, leaves become sticky from aphid excrement. Black sooty mold grows on fungus to shade leaves. This reduces quality of nut meats.	Biological control OR Ambush, Asana, Malathion, Diazinon, or Lorsban OR Thiodan 2 C.O EC at 3-4 qts per acre..	Aphids are attacked by a number of parasites and predators. Reducing the number of insecticide applications will help conserve these natural enemies Same as for codling moth. Do not apply after husk split. General use insecticide. 0 day PHI.
MITES: European red mites (ERM), two spotted spider mites (TSSM) ERM=*Panonychus ulmi* (Koch) TSSM=*Tetranychus urticae* (Koch) Spider mites feed on leaf undersides and cause them to appear bronzed and webbed. ERM overwinters on tree and TSSM overwinters on weeds. See E-42 "Spider Mites on Ornamentals" for more information.	Dormant application of 3% superior oil (not for TSSM). Monitoring	Apply when trees are dormant, temperatures are above 40° and there is no danger of freezing. For 30 days, do not follow with application of Morestan, Sevin, Cygon, Captan, Folpet, Pyrene, or sulfur compounds. Inspect plant leaves for mites and webs.

Walnut Insects continued		
INSECT	TREATMENT	COMMENTS
Continued Mites:	Late spring, summer application of 1% superior oil. OR Vendex 50WP, or 4L at 4-8 oz per 100 gal. OR Morestan 25WP at 1-1.5 lbs per acre.	Be sure leaves have fully expanded. Follow precautions for dormant application. 0 day PHI. Do not apply after husk split. Up to 2 applications per season. 14 day PHI. Do not apply after husk split. Kills adults and eggs. 30 day PHI. Do not apply after husk split.
SCALE INSECTS: There are several species of scale that attack walnuts. Most important is the oystershell scale. *Lepidosaphes ulmi* (L.) Crawlers, the mobile (1/16") stage of oystershell scale are present from mid-May to June and again during the 3rd week of July.	Apply 3% concentration of superior oil in dormant season. OR 1% application of superior oil. OR Biological control	See Mites. When crawlers are active. Follow restrictions outlined for dormant applications. Scale insects are attacked by several predators and parasites. Reducing insecticide applications can help conserve these beneficial insects.

INSECTICIDE TRADE NAMES AND COMMON NAMES	
Trade Name	**Common Name**
Ambush	permethrin
Ammo	cypermethrin
Asana	esfenvalerate
Bacillus thuringiensis	Bacillus thuringiensis
Cygon	dimethoate
Cymbush	cypermethrin
Diazinon	diazinon
Guthion	azinphosmethyl
Lorsban	chlorpyrifos
Malathion	malathion
Morestan	oxythioquinox
Pounce	permethrin
Sevin	carbaryl
Supracide	methidathion
Thiodan	endosulfan
Vendex	hexakis

***Read and follow all label instructions. This includes directions for use, precautionary statement (hazards to humans, domestic animals, and endangered species), environmental hazards, rates of application, number of applications, reentry intervals, harvest restrictions, storage and disposal, and any specific warnings and/or precautions for safe handling of the pesticide.**

Leaf Spot Diseases Of Black Walnut

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Growing black walnut in plantations can aggravate disease problems, especially leaf diseases. Factors that lead to infection and increased disease incidence and severity are high humidity (>98%), free moisture on leaves (rain, dew, fog, or from irrigation), low light intensity, and temperatures around 21° C. There are four common leaf diseases of black walnut, microstroma white mold, bull□s-eye leaf spot, mycosphaerella leaf spot, and walnut anthracnose. The most common and most serious of these is walnut anthracnose. All but microstroma white mold can cause premature leaf loss resulting in reduced growth, increased susceptibility to other diseases, and reduced quantity and quality of nuts.

All of these fungal diseases have a similar biology. Primary infections occur in the spring, May through early June, from ascospores emerging from fruiting bodies on overwintered leaves on the ground. Once primary infection occurs, lesions appear on leaves within a couple of weeks. Subsequent secondary infections occur on leaves throughout the summer by wind-dispersed spores (conidia) produced in these lesions. Production of spores increases gradually during July and reaches maximum numbers in August. The infected, fallen leaves serve as the reservoir for next year□s inoculum, completing the annual life cycles of these fungi.

Microstroma White Mold -
Microstroma white mold (or downy leaf spot), caused by Micrcostroma juglandis, is more unsightly than damaging. This disease does not kill the leaf and is not known to cause defoliation. The effect to the tree is minimal, probably resulting in a minor reduction in photosynthesis. Symptoms are a yellowish discoloration on the upper surface of the leaf (fig. 1), and a whitish growth on the underside of the leaf, often concentrated along the veins (fig. 2).

Bull's-Eye Leaf Spot -
Bull's eye leaf spot (or zonate leaf spot), caused by Grovesinia pyramidalis (asexual state = Cristulariella moricola) causes leaf spots and premature defoliation. Maple, hickory and many common weeds are also infected. Symptoms are unique in that the dark lesions on leaves are rounded and have concentric white rings, giving the spot a target-shaped appearance, hence the name bull's-eye leaf spot (fig. 3).

Mycosphaerella Leaf Spot -
Mycosphaerella leaf spot, caused by Mycosphearella juglandis (asexual state = Cylindrosporium juglandis) causes leaf spots that are angular, reaching a maximum size as large as 4mm in diameter (fig. 4). By midsummer, as lesions increase from secondary infections, affected trees look chlorotic or yellow. Coalescing lesions produce a vein pattern or a leaf scorch symptom. By late summer, severely diseased leaves fall, especially in dry weather.

Walnut Anthracnose -
The most serious and widespread leaf disease of black walnut is walnut anthracnose, caused by Gnomonia leptostyla (asexual state = Marssonina juglandis). The disease results in leaf spots ranging in size from a few mm to 1.25 cm in diameter. Dark spots first appear on the leaf blades and petioles in the spring (fig. 5). The older leaves in the lower and interior portions of the tree crown are most severely affected, show the most chlorosis and are the first to show premature leaf fall. The leaves infected early in the year are most important for photosynthesis during the critical period of nut formation and severe infections cause reduced yield and nut crop failure. The fungus may infect the nuts directly (fig. 6), causing nut meats to shrivel and darken.

Adjacent trees in plantations may exhibit varying levels of infection, indicating existence of natural resistance to anthracnose. This resistance is highly heritable, with provenances from the relatively arid western edge of the natural range of black walnut (Kansas and Oklahoma) being most susceptible. This is likely due to the limited natural selection for anthracnose resistance in this region.

When evaluating differences among cultivars in susceptibility to anthracnose one must take into account the nut load (William Reid, personal communication). Non-fruiting shoots have more leaves and the terminal leaves are younger. These younger leaves have fewer anthracnose lesions because they matured later in the season after the primary infection period for the fungus had passed. Thus, a tree producing a large quantity of nuts will look more susceptible to anthracnose than a tree producing few or no nuts.

CONTROL

Most of the research on control and management of foliar diseases of black walnut has been directed against walnut anthracnose, although many of the methods available to growers probably would be effective against all the walnut leaf diseases.

Cultural management is the best approach to minimizing the impact of leaf diseases, particularly in plantations. First, plant only seedlings known to be resistant to disease. Presently, growers are at the mercy of nut collectors when planting seedlings. It is incumbent on nurseries to only sow nuts from known sources, preferably from resistant trees within the region where seedlings ultimately will be planted. Avoid shipping seedlings from the western area of the natural range of black walnut to other regions. In established plantations, growers should observe which seedlings exhibit symptoms and select against the most susceptible individuals during thinning operations.

Most cultural practices should be directed toward reducing free moisture on leaves. Dense stands are more susceptible to disease because of increased humidity, caused by reduced wind flow through these stands and the resulting increase in free moisture on leaf surfaces. Thinning improves drying of leaf surfaces and reduces leaf shading between trees thereby reducing incidence and severity of disease. Also, UV light kills spores.

Plantations should be oriented in long rows perpendicular to the prevailing winds in spring and summer as this has been shown to promote leaf drying. Spores are spread by wind, gravity, and probably insects, so avoid planting small trees under or downwind from large infected trees. Ponds, lakes and streams release heat gradually on cool nights, so establishing plantations near bodies of water, particularly on the lee side, lessens dew formation on leaves. Avoid establishing plantations in cold seeps or small openings since this leads to increased dew formation. Avoid overhead irrigation.

Weeds also contribute to higher relative humidity in and around seedlings, so preventing leaf diseases is one more reason growers should control weeds either through cultivation or herbicides. Cultivation after leaf fall has the added benefit of incorporating infected leaves into the soil, thereby promoting their decomposition. Depending on the crop, intercropping may contribute to increased humidity. Growers will have to weigh the risk of increased potential of leaf diseases versus the benefits of intercropping.

Interplanting autumn olive, hairy vetch, crown vetch, or serecia lespedza may reduce infection by increasing total foliar nitrogen and by preventing primary infections due to increased decomposition of fallen black walnut leaves thereby lowering ascospore production.

April and June applications of nitrogen have been shown to reduce infection as well as increase growth of trees. However, □ High rates of nitrogen stimulate non-fruiting shoots to grow late into the summer well after the infection period. These leaves give the tree a healthy appearance and mask the defoliation of older leaves□ (William Reid, personal communication). Soil application of ammonium sulfate, ammonium nitrate, and urea all are effective, although foliar application of urea is not. The addition of phosphorus and potassium has been shown to diminish the benefit of nitrogen fertilizer.

Direct control using fungicides can be effective, although the availability of suitable materials is in question. Benomyl has been shown to be the most effective of all the fungicides tested, however, it no longer carries a black walnut label. Only Syllit (Dodine)is registered for nut crop use. For landscape use, Botran, Daconil, Nova and Ziram have a black walnut label. Since the status of all agricultural chemicals are always under review, contact your local extension agent for the latest information.

Since infections can occur anytime during the growing season, timing of applications presents a problem. A practical approach is two applications, the first applied the last week in May to prevent the primary infection by ascospores, and the second applied the first week of July to inhibit secondary infection by conidia.


Figure1. Microstroma on upper leaf surface


Figure 2. Microstroma on lower leaf surface


Figure 3. Bull's-eye leaf spot


Figure 4. Mycosphaerella leaf spot


Figure 5. Anthracnose on leaves


Figure 6. Anthracnose on nuts

REFERENCES

U.S.Department of Agriculture, Forest Service. Burde, E. Lucy, ed. 1988. Walnut Notes. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 5.01-5.02

U.S.Department of Agriculture, Forest Service. Ohman, H. John, dir. 1977. Manager's Handbook for Black Walnut. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 22 p.

Sinclair, W.A., H.H. Lyon, W.T. Johnson. 1987. Diseases of Trees and Shrubs. Comstock Publishing associates, Cornell University Press. 574 p.

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www.nutgrowers

PART 5

HARVEST AND POST HARVEST

Traditional Methods Of Harvesting, Transporting, And Storage of Eastern Black Walnut Nuts

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INTRODUCTION

The eastern black walnut nut industry is based on a totally wild crop with the nut producing segment of the resource being generally made up of trees that are 8-10 inches in diameter and larger. These individuals have almost exclusively been planted by squirrels and have been permitted to survive in fence rows, field borders, lawns, and roadsides throughout the range of the species. Some of these individuals have been encouraged to grow and selected from competition, but are the remnants of prior selective log harvests. The nut crop is basically a gift of nature. Very few of these trees are impacted by fertilization, pest control, or other cultural practices and their crop size is highly variable from year to year.

BUYING STATIONS

Buying station contractors are a diverse group of businesses and individuals. Contractors receive the nuts in the husk and are responsible for operating the hulling machine, recording the weights of in-shell black walnuts that are purchased, storage of the black walnuts at their site until shipping, and also the disposal of the husk that is removed by the hulling machine. For operators to have a successful operation, all these areas of responsibility must be done efficiently and properly. Operators are paid a commission based on the number of pounds that they purchase on an in-shell weight basis. The current commission rate in 1998 paid to each operator is $3.00 cwt. based on the on-site scale weight. This weight is measured after the customers black walnut have been processed through the hulling machine which removes the outside husk off the in-shell nut. Most operators dispose of the husk on pastureland using a manure spreader to distribute the husks. Test show that the Ph level of husk material is neutral to alkaline. The husk tends to run approximately 1% in nitrogen and will also help to build up the organic matter within the soil. After hulling, the in-shell nuts are placed into mesh bags, tied and placed on the scales for weighing. Most buying locations use small platform scales to do the weighing of each individual's nuts that are purchased. The name of the picker and the purchase weight are then recorded on a buy sheet which is provided to the operator. Operators can mail these sheets daily, weekly, or monthly depending on their financial ability. Hammons Products Co. then returns payment through the mail with the amount for the purchased nuts along with their commission for the pounds that were purchased. If operators bring in their buy sheets into the main office at Stockton, Missouri they can receive payment immediately at the time.

Buying station locations need to have plenty of room for the receiving of nuts coming in, allowing traffic to move freely about without incident. Each location will also need plenty of space for storage of the in-shell purchased nuts along with the ability to dispose of the husk as the buying season progresses. Areas that drain properly and tend to dry out quickly help locations to be more effective and efficient as fall weather is unpredictable and usually wet as winter approaches.

HARVEST SEASON AND HARVESTING METHODS

The eastern Black Walnut buying season begins October 1st each year and extends into the second or third week of November. With the buy season only five to six weeks in length, this makes for very intense and aggressive harvest. The volume of nuts needed and purchased each year is not controlled by the length of the buying season, but more by the suggested purchase price of the nuts at the buying locations. Current pricing is based on supply and demand and flexible pricing is being implemented on a more regular basis each new year. However, Mother Nature plays a very large and important role in the volume and quality of crop that is available for purchase.

Through the years, the black walnut nut industry has not changed much in the way the nuts are harvested. Usually in late September to early October the nuts mature and drop to the ground where they are still picked up by hand one at a time. This is a very labor intense harvesting method and currently continues to remain that way. The nuts are picked from under trees located in fence rows, pasture land, lawns, and even black walnut orchards throughout the Midwest and eastern United States.

STORAGE AND TRANSPORTATION

Storage and handling of the bagged in-shell nuts is one of the most important areas of responsibility that the operator has. Operators need to place the bags on pallets, and store the nuts outside which helps air to circulate through out the mesh bags and begins the drying out process. Although the nuts may get rained on in an outdoor storage location, they will quickly begin drying as a result of outside air movements. When the in-shell nuts are stored in a confined space without air movement, the nut will begin showing signs of mold on the shell. The kernel will then begin pulling moisture from the outside shell into the kernel, thus increasing the kernels moisture content and prohibiting proper drying. Over extended periods of time in this situation, the kernel will begin turning darker in color and becoming poor in quality.

Locations which buy large amounts of black walnuts quickly realize how much labor and space is needed to handle and store large volumes of this tasty nut. Mesh bags are then loaded on or into trailers and transported to the shelling facility for further processing. All bags are normally loaded and unloaded by hand both at on-site buying location and at the shelling facility. Using this process on literally millions of pounds of in-shell nuts is a very strenuous and a highly laborious effort not only at the operator level, but at the shelling plant as well.

PLANNING FOR THE FUTURE

With more eastern black walnut orchards being planted each year, advanced harvest techniques along with improved handling practices must be improved upon in the near future. Implementations of new purchasing procedures dealing with percent yields, moisture content, and kernel color are all areas that will need to be explored and expanded on. Advancements in tree genetics for nut production will need to reach levels where land owners are willing and wanting to plant eastern black walnut trees for a cash crop with returns on a per acre basis being equal to other agricultural commodities. When all of these new practices and procedures are in place, the black walnut nut producing industry will truly reach commercialization levels.

Black Walnut Harvesting Costs--The 50 Percent Factor

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Ultimate success of agroforestry systems, especially those that incorporate nut tree plantations with intercropping, will depend on their profitability. As with more traditional crops, harvesting and labor costs are major considerations. As much as half or more of the nut crop income from a black walnut agroforestry system may be required to pay the harvesting costs.

It is commonplace that at least 50 percent of the nuts harvested from scattered native walnut or pecan trees goes to itinerant or contract hand nut pickers. Black walnut pickers often receive the whole crop. Contract pecan harvesters with mechanized harvesting equipment charge 50 to 70 percent of the crop for their services. However, they also may provide other pre-harvest labor such as pruning, stick picking and mowing, even spraying for insects.

While a 50 percent charge for contract harvesting may seem exorbitant to a plantation owner, it must be determined: "50 percent of what?"

A dedicated hand picker might harvest 500 pounds of hulled black walnuts in a day. At 10 cents per pound that's only $50 a day. It's quickly evident why most black walnut pickers do not want to share the proceeds. Even in a plantation setting where the nuts are abundant and pickers do not need to travel far between trees, the daily wage still would be quite small for the labor involved.

Plantation size and the ultimate growth of the industry are closely tied to how many pounds of nuts can be harvested in a day and at what cost.

If we accept that one person can hand harvest up to 500 pounds of hulled black walnuts in an 8-hour day, we can begin to measure nut harvest efficiencies. The 500-pound marker certainly isn't an average of what most hand pickers actually harvest. Most do not or cannot or will not work 8 hours a day. It has been proven on the Hammons Sho-Neff Plantation at Stockton, Mo., that dedicated pickers can harvest that amount.

It also has been shown from historical weather records that there are an average of 20 excellent harvesting days in the fall. Of course, there can be more in some years, less in others and growers will definitly extend the season by working some "not so good" days. But for purposes of comparison, lets stick with the 20 days and 500 pounds per day for each worker. That means that a single picker can harvest only 10 acres of black walnut trees that produce an average annual crop of 1,000 pounds per acre (20 x 500 = 10,000 pounds).

If the plantation yields 2,000 pounds of nuts per acre, a single picker could harvest only 5 acres. The reality then is that a plantation owner can plant only the number of acres he or she has labor or equipment available for the harvest.

If hand labor is not available, and it probably won't be; who else but the plantation owner is going to work 8 hours a day for $6.25 an hour (500 x 10cents = $50 / 8 = $6.25), then mechanical harvesting no longer is an option, but a necessity. In fact, hand labor other than family labor for picking nuts for their own use or a limited niche market, probably isn't an option at all. The only time hand labor would be attractive would be in the case of a limited acreage of high-value nuts, processed and direct-marketed to special buyers. The price would have to be set so it covers production, harvesting, processing and marketing costs plus a reasonable profit.

However, for this example, let's assume we are producing for the commercial nut market (Hammons Products Co.).

It is a foregone conclusion among pioneering black walnut plantation owners that some kind of mechanical harvesting is necessary. Several approaches have been tried.

Some of these systems do little more than remove some of the back-breaking stooping and bending work. Spreading tarps around trees to collect falling or shaken nuts may actually increase labor costs. A more mechanized approach of mounting tarps on a tractor frame may also increase costs and not gain any economies.

The modified golf ball retrieving units offered by Bag-A-Nut may be handy for harvesting a small orchard, but the efficiency of these small push-type or lawn tractor-mounted units is questionable. Cost of the 16-inch model is about $250 while larger units may cost several hundred dollars.

At least two commercial nut harvesting systems lend themselves for adaptation to black walnut. The first is English walnut harvesting equipment, manufactured mostly in California where the English walnut is most prevalent. It appears to perform well enough, but initial cost may be more than the black walnut market can bear. The system now in use at Hammons Products Company at Stockton, Mo. is made by Weiss-McNair. This sweeper-harvester combination costs about $35,000 new. A tree shaker would add another $5,000. Total system cost would be about $40,000 not including tractor and transport equipment necessary. We assume most multi-crop farming operations would already have this equipment. The purpose here is to compare only the costs of equipment specific to the nut harvesting operation.

The second harvesting system under consideration is a modified pecan harvesting machine manufactured by NH Savage of Medill, Oklahoma. In preliminary trials using the company's smallest model, it was determined that the harvester will pick up walnuts (with hulls on), but needs several modifications. A larger screening chain with at least 3.5-inch openings is necessary to allow the largest black walnuts to pass through while still screening out the largest sticks and other trash. The augering system, both the horizontal transport and the elevating augers, should be increased in diameter to handle the large walnuts with hulls on. It might be possible to replace this augering system with a conveyor belt that would be useful for both walnuts and pecans.

The trash screen on the elevator auger also must be opened up to 3/4 inches to allow more trash, especially crushed hull, to be expelled. However, some of the crushed hull would be eliminated by the larger augers or conveyor.

It also is suggested that the pickup header on the machine needs to be free-floating with a gauge wheel to accommodate uneven ground.

With these adaptations, it is felt that the NH Savage equipment would perform well enough. Savage recently introduced a new model pecan harvester with 6-foot header that incorporates some of these design changes. However, it has not been tested on black walnut.

It is roughly estimated that an NH Savage harvester of equivalent size to the Weiss-McNair unit could harvest up to 30,000 pounds of black walnuts with hulls in an 8-hour day. That would yield about 12,000 pounds of hulled nuts per day (40 percent of total weight).

Now we have to get back to the question: "50 percent of what?"

The capability of the harvester mentioned above would allow an operator to cover 8 to 10 acres per day when the per-acre yield is between 1,000 and 1,500 pounds of hulled nuts. From experience in pecan plantations, it is estimated that 10 to 12 acres a day is about all that can be covered no matter what the yield may be. Therefore, our harvesting capability may set the minimum yield goals we strive for.

Harvesting capability also will largely determine the number of acres needed to reach the economic potential for ownership of the equipment. The harvesting capacity used above would allow an operator to harvest 40 acres yielding 1,000 to 1,500 pounds of black walnuts per acre in 3 to 5 days. Long-term weather records indicate that most areas of Missouri have an average of 20 days of open harvesting weather each fall. We could extrapolate that we might be able to use the harvesting equipment for at least 20 days most years on at least 160 acres. That number of acres, whether owned or under custom harvest, would spread the cost of the equipment over the most economic time period.

Cost of machinery ownership based on 160 acres, or better yet, 160,000 pounds of hulled nuts, would be figured by the following formula: Original cost of machine minus salvage value (10 years) divided by 10 plus interest [original price plus salvage value divided by 2 to get an average annual interest value] times 10 percent plus maintenance [2 percent of original investment].

The annual cost of a harvesting machine selling for $15,000 would be $2,300. A more useful cost figure is cost per pound. If an operator could harvest 160,000 pounds annually, the per-pound cost would be almost 1.5 cents.

Of course, there are other machines and expenses in this harvesting system. A tree shaker at a cost of approximately $5,000 would be necessary. How the nuts are marketed, whether in the hull and transported to a buying station, or hulled on the farm for retail or wholesale marketing will determine the need for buying a huller and washer. These two items could add $1,500 each, perhaps more. As trees become more mature, it likely will become necessary to use a trash or stick rake to remove debris before harvest. This could add another $3,000. Total cost for new equipment with the NH Savage unit could reach $26,000 or 2.5 cents per pound or more cost.

Labor to operate the machinery also must be added. It most likely would require a three-man team, especially if the hulling is done on the farm simultaneously as the harvesting. Taking the nuts to a commercial huller might reduce farm labor but would increase per-pound cost by 3 cents (normal huller operator compensation).

Three men at $6 per hour times 8 hours equals $18 times 8 equals $144 times 20 days equals $2,880 divided by 160,000 pounds equals 1.8 cents a pound.

Other machinery costs such as farm tractors (most likely two) plus wagons or truck for transportation must also be added. That most likely would increase harvesting costs another cent or two.
Harvesting costs could easily mount to 5 or 6 cents per pound or more under the best of conditions, depending on total pounds picked. That's half or more of the current commercial price of 8 to 10 cents a pound for hulled nuts at a commercial huller. Add 3 cents to that if nuts are hulled on the farm.

The best of conditions dictate that a harvester must be operating in a plantation environment where nuts are conveniently accessible and plentiful. A crop of at least 1,000 pounds per acre seems to be a necessity just to make mechanical harvesting feasible.

These figures are predicated on a minimum yield of 160,000 pounds harvested in 20 days. Any change in that figure, i.e. less than 160,000 pounds, increases rather dramatically the cost of harvesting equipment on a per-pound basis. Extending the acreage or the season is not a real option since days of optimum harvesting conditions are limited.

Although a reduced yield likely would result in reduced labor costs (fewer days), the annual machine ownership costs would be the same.

It would appear that under current nut pricing conditions, even with ownership of harvesting equipment, the cost of harvesting is likely to be at least half the crop.

The solution to this dilemma does not lie in higher yields, at least not a big part of the solution. The machine's capacity is limited to the number of nuts that can be picked up in 20 harvesting days. A heavy crop might increase that capacity somewhat.

The real solution lies in pricing the crop at a reasonably profitable level.

BLACK WALNUT AGROFORESTRY -- MISSOURI BASIC SYSTEM (ALTERNATIVES)

This system information sheet can be used to collect alternative agroforestry system cost, income and timing information needed to calculate profitability and make comparisons with the basic system.

Alternative System Design:

Row and tree widths -- (40 by 20 feet = 54 trees/acre)
Site Index -- (65)
Rotation = number of years to final harvest -- (60)
Tree species -- (Eastern Black Walnut)
Planting method -- (post hole digger)
Rootstock -- (selected cultivar bareroot seedlings)

Field grafted -- (custom grafted = $3/tree)
Alley crop -- (orchard grass/red clover)
Salable crops -- (nuts, timber, hay)

Crop Yields:

Nuts: (Year 11-15 = 500 pounds/ac.)
(Year 16-20 = 750 pounds/ac.)
(Year 21-30 = 1,000 pounds/ac.)
(Year 31-40 = 1,500 pounds/ac.)
(Year 41-60 = 2,000 pounds/ac.)
Price: (25 cents/pound)

Timber:
(Commercial Thinning at Year 26. Remove 27 trees at 12 in. DBH with 9 ft. log = 16 board ft.)
Price: (50 cents/board ft.)

Final Harvest:
(27 trees @ 25 inches DBH with 9-ft log = 180 board feet)
Price: ($1/board foot)

Hay: Annual net income ($60/acre/year)

(Livestock = annual net income)
(Annual crops = annual net income)
(Long-term crops--ornamentals, ginseng, etc. use cost and income by Years.)
(Services--lease hunting, etc, use annual net income)
(Government programs and cost share = annual net income)

Costs of individual practices:

Site preparation: ($10/ac.)
Rootstock: ($1/seedling = $54/ac.)
Planting: ($1/seedling = $54/ ac.)
Grafting: ($3/tree) (70% success rate annually)
(Year 3 = 54 trees x $3 = $162/ac.)
(Year 4 = 16 trees x $3 = $48/ac.)
(Year 5 = 4 trees x $3 = $12/ac.)
Herbicide: Application cost ($5/ac.)
Chemical cost (Year 1 thru 6 = 3-ft. strip on each side of row = $8/ac.)
(Year 7 thru 8 = 4-ft. strip each side of row = $9/ac.)
(Year 9 thru 60 = 6-ft. strip each side of row = $11/ac.)
Fertilizer: (60-30-30 annually beginning Year 2 = $27/ac.)
(Application cost: $5/ac.)
Overseeding: (Red clover overseeded every 4 Years at 8 pds/ac. x $2 = $16/ac.)
(Application cost: $4/ac.)
Pruning: (Year 7 = $14/ac.)

(Year 12 = $14/ac.)

Management: (All those odd annual jobs we hadn't counted on: $7/ac./Year)

Other specific practices needed for this alternative system: (Cost/ac, Years performed)

SPECIALIZED AGROFORESTRY PRACTICES COSTS

Planting:
Dibble Bar -- .20/tree
Transplanter -- .12/tree
Post Hole Digger -- .50/tree
(Double these rates if have custom contractor perform service)

Seedlings:
Missouri State Nursery -- .50 ea. (after culling half)
Selected cultivar -- $1 ea. (greenhouse grown)
RPM selected cultivar -- $8 ea. (in 2-gal. pot)
RPM grafted cultivar -- $12 ea. (in 2-gal. pot)

Weed mats/inc. installation:
$1 ea. (no herbicide application until Year 5)

Field Grafting: (Includes scionwood) $3/tree

Pruning/hauling debris: .26/tree

Labor: $7/hour

(The accompanying table demonstrates the economic necessity of harvesting as many pounds of nuts as possible within the ideal harvesting period. Machinery ownership cost (interest, depreciation and maintenance) are the same each year no matter how many pounds of nuts are harvested. Hourly tractor and labor costs vary with the amount of time required to harvest the crop.)

MECHANIZED HARVESTING COST (PER POUND) FOR EASTERN BLACK WALNUT

Number of Harvesting Days	1	2	3	4	5	10	15	30
Machinery Ownership Costs	$4,500.	$4,500.	$4,500.	$4,500.	$4,500.	$4,500.	$4,500.	$4,500.
Hourly Tractor/Labor Costs	$288.	$576.	$864.	$1,152.	$1,440.	$2,880.	$4,320.	$8,640.
Total Annual Cost	$4,788.	$5,076.	$5,364.	$5,652.	$5,940.	$7,380.	$8,820.	$13,140.
Cost per pound @ 5,000 lbs.	$.96	$.50	$.36	$.28	$.24	$.14	$.12	$.08
Cost per pound @ 10,000 lbs.	$.48	$.25	$.18	$.14	$.12	$.07	$.06	$.04

Mechanical Harvesting of Eastern Black Walnut Nuts

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INTRODUCTION

It is generally accepted that for the commercial production of Eastern Black Walnut nuts to be successful that mechanized harvesting will be a must. Most, if not all, commercial tree nut crops in North America are now harvested by machine. This is an important consideration for the introduction and development of Eastern Black Walnut nut harvesting systems. It will not require the industry to start at ground zero, but rather to learn from others and make rapid gains. The purpose of this paper is to review recent machine harvesting experiences, field needs for mechanical harvesters, machines necessary for a successful harvest and cultural practices to facilitate the process.

HARVESTING EXPERIENCES

The harvest of Eastern Black Walnut nuts is not unlike any other agricultural crop. The crop matures within a specific time period and an optimum time for harvest occurs. With a planting of unknown genetic material the maturity dates will be fairly widespread. However, with blocks of improved varieties the maturity issue will be much less complicated and the grower will quickly be able to determine an optimum harvest schedule. The basic goal for harvest should be to remove the nuts from the trees, remove the husk from the nuts and reduce the moisture content to a storable level as soon as possible after maturity has been reached. The traditional harvest season is basically October 1st to November 15th when dependent upon the natural fall of the nuts. It is believed that this schedule could be advanced by perhaps a week or more through the use of a tree shaker. Here again single variety blocks would simplify the decision making.

One of the major benefits of machine harvesting is employee acceptance. In today's society and work environment this is very important. Managers must be able to create productive, efficient and economical harvest systems.

A Weiss-McNair harvest systems has been used at Hammons Sho-Neff Plantation and two other projects for the past four years (not all sites all years). The system includes a tractor mounted blower and sweeper and a tractor powered harvester. The retail price 4 years ago was approximately $35,000.00 for the package. These machines have been used to harvest as little as 350 lbs./acre and as much as 1200 lbs./acre. They are manufactured in Chico, California and have been widely used by the English walnut, pecan, almond and other tree nut industries. Each year similar machines cover hundreds of thousands of acres. In harvesting several hundred acres of less than perfect sites the machines have proven to be quite durable and dependable.

FIELD NEEDS

To successfully harvest with the shaker-blower-sweeper-harvester system requires a relatively smooth surface. The fields at Hammons Sho-Neff Plantation have been carefully prepared and cropped in an agroforestry management system for as many as 24 years. The best harvest conditions require the grass to be 4 inches or less in height, relatively smooth soil surface, no dead branches and a minimal rise within the tree row.

One must remember that the Southwest Missouri region receives 40+ inches of precipitation per year. Wet field conditions can keep nut harvesting machines out of the field for a week at a time. When the nuts are fresh, firm, green and round they can be easily moved with a blower and the sweeper. However, when these same nuts are older, black, somewhat flattened and frozen to the ground they do not roll very easily. Another argument for a speedy, early harvest. In addition to these challenges is the need to remove dead branches from the harvest areas prior to hay and nut harvest.

Machine harvesting in Southwest Missouri has demonstrated the importance of soil conditions and a quality ground cover. With regional rain fall conditions it would appear that bare soil IS BASICALLY OUT OF THE QUESTION FOR THIS AREA. While harvesting at Sho-Neff Plantation the weed control band must be avoided with the tractor tires to prevent creating ruts during most seasons. It is believed that a well managed ground cover of bluegrass and white Dutch cover provide a near ideal harvest surface.

On some harvest sites with sparse ground cover and a gravely soil it is somewhat difficult to keep the small stones from entering the nut cart along with the nuts. Without a de-stoner tank the stones create real problems in the hulling machine.

SUMMARY

Mechanical harvesting systems for Eastern Black Walnut nuts should allow the grower to take advantage of new technology and reduce personnel requirements. To do a satisfactory job of harvesting will require proper management of the soil surface and the ground cover used to prevent soil erosion and provide harvest and access support. One of the negatives associated with the machine harvest is that additional vehicles in the planting create more soil compaction.

The machines to mechanically harvest Eastern Black Walnut nuts are now basically available with some new products yet to come. Machines are just one piece of the puzzle. Improved genetics and improved cultural practices will blend with the machine to make the Eastern Black Walnut nut crops in the future a viable land management enterprise for growers.

EQUIPMENT LIST FOR MACHINE HARVESTING

Weiss-McNair	
Blower-Sweeper-Harvester	$35,000.00
Savage	
Shaker (PTO driven)	$5,000.00
Tractors	
John Deere 4020 (harvester)	$7,500.00
John Deere 3020 (sweeper & blower)	$7,500.00
Hesston 780 (shaker)	$8,000.00
Total Equipment Costs	$63,000.00

MANUFACTURES OF NUT HARVESTING EQUIPMENT

Harvesters, Sweepers and Blowers:

- Weiss-McNair, Inc.
  531 Country Drive
  Chico, CA 95928
  Tel: 916-891-6214

- Flory
  PO Box 908
  4737 Toomes Rd.
  Salida, CA 95368
  Tel: 209-545-1167
  Fax: 209-545-4924

- Ramacher
  531 Country Drive
  Chico, CA 95928
  Tel: 916-891-6214
  Fax: 916-891-5905

- Savage Equipment
  400 Industrial Drive
  Madill, OK 73446
  Tel: 405-795-3394

Catchment Frames:

- Weldcraft Industries, Inc.
  PO Box 11104
  Terra Bella, CA 93270
  Tel: 209-784-4322
  Fax: 209-784-4620

Shakers:

- Compton Enterprises
  2434 Dayton Road
  Chico, CA 95928
  Tel: 530-895-1942
  Fax: 530-895-0760

- Orchard-Rite
  1816 South Van Ness
  Fresno, CA 93721
  Tel: 209-237-3222

- OMC
  2700 Colusa Highway
  Yuba City, CA 95993
  Tel: 916-673-2822
  Fax:916-673-0296

Beyond The Nuts.........

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The information presented in this paper is based on the assumption that you have planted your walnut trees, are interested in harvesting nuts (to provide a modest, annual income) and eventually are interested in harvesting the trees and selling the wood. While the production of these two basic products (nuts and wood) from the same tree is quite possible and very common, there are also several potential pitfalls. Remember, tree growth and wood quality are controlled by three factors: genetics, age, and environment (this includes management). To a large degree, nut production is controlled by these same three factors! However, a good nut producing tree may have certain characteristics that may not make a high-quality walnut veneer tree! With that in mind, let us look at the probable impact of some common management practices on tree growth and wood quality. While there have been many examples of guidebooks discussing walnut stand management -- USDA General Technical Report NC-38 by Schlesinger and Funk (1977) as an example -- none of these discuss wood quality. In the Fourth Black Walnut Symposium, Phelps (1989) addressed the tree growth-wood quality relationship from the wood properties perspective.

Size -- Bigger logs bring higher prices assuming that stem quality is the same. As a guideline, sawlogs should be at least 8'6" feet long (the 6" is trim allowance) and 12 inches in diameter inside the bark (DIB) at the small end of the log. You may have a niche or specialty market for smaller logs but usually smaller logs are best suited for firewood. Typical veneer logs should be larger in diameter, at least 18 inches DIB. As a good guideline, the bottom or butt log of the tree usually contains the highest quality wood – either lumber or veneer. There is a direct relationship between log grade and lumber grade.

Logs should be round, straight, and have as many defect-free faces as possible. "A face" is a quarter of the tree's circumference. Defects include cracks, knots, bird peck, fire damage, logging damage, etc. Top grade veneer logs will have four defect-free faces. The better sawlog grades should have two, adjacent defect-free faces. The higher in the stem the log is taken from, the more knots and branches and the lower the amount of heartwood. Sapwood and knots are not desirable characteristics in walnut!

Pruning -- As an example, the most desirable veneer logs would have a long clear bole, say 17 feet or more. However, veneer buyers may buy material that is only six feet or longer in certain circumstances. Assume you have planted these walnut trees on a 10' x 10' spacing. You have chosen the site well, you have used improved or selected planting stock, you've done the weed control, you've done everything imaginable to get the stand well-established. You notice that some of the trees are starting to have branches shooting off to the side, so you prune them back. How high are you going to prune? When is the best time to prune? How big a branch should I prune?

What most people overlook is the fact that pruning is actually a deliberate wounding of the tree! Even when the pruning is done following all the well-established guidelines for pruning, you've wounded the tree. Depending on the tree itself, this wound may heal quickly, it may heal slowly, or -- worst case -- it may never heal.

The general recommendation that may be made is that pruning should be done at an early age and limited to small diameter branches (say less than 1" in diameter). Early pruning will allow the production of the maximum amount of clear wood. As to how many limbs to remove, there are no absolute rules. Limbs hold leaves which are the photosynthetic factories for growth. The more limbs (e.g. leaves) you remove, the more the impact on growth. No more than 25% of the crown area should be removed at a time. While limbs larger than 1" can obviously be removed, the wound's ability to heal in a timely fashion is questionable. Vigorous healthy trees will heal wounds faster than trees in poor health. Pruning height may be practically limited. You may want to prune high enough to allow passage for tractors, etc. through the stand.

Thinning -- Typically, thinning is thought of as removal of poorly formed trees, low vigor trees, diseased trees, etc. From a traditional forest management standpoint, thinning is either pre-commercial (i.e. the cut trees are left on the ground) or commercial (the removed trees are large enough for some type of product recovery). In either event, the result is increased water and nutrient availability for the crop trees. In some instances, there have been reports of increased levels of limb-related defects associated with heavily thinned hardwood stands.

In the 1940s, Benson Paul , a US Forest Service silviculturist, reported that open-grown black walnut had higher density than did forest-grown walnut. Open-grown was defined at that time as "trees growing singly or in small scattered groups in pastures and relatively open farm woodlots". This might be analogous to stand densities seen in many agroforestry configurations. Later Paul recommended that management practices producing conditions similar to those where open grown walnut occurs be followed.

In 1973, other scientists suggested that open grown walnut would tend to be forked and limby while forest grown walnut would have a straight, clear stem. According to them, the forest grown stems would have a dark colored heartwood with a narrow sapwood band while open grown trees would have lighter heartwood and wider sapwood rings.

One of the more desirable traits of walnut wood is its even texture. Some studies have suggested that faster-growing plantation trees had wider growth rings which in turn have wider latewood zones. This results in a reduction in vessel area in the cross-section which results in poorer wood texture. On the other hand, stand management favors a more uniform wood texture.