Cultivar Evaluation and Development for Black Walnut Orchards

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ABSTRACT—Black walnut is an underdeveloped orchard crop. Hundreds of cultivars have been named but a commercial orchard industry has not developed. The horticultural characteristics of currently available black walnut cultivars are reviewed. Important cultivar traits include: leaving date, flowering date, growth habit, disease susceptibility, yield, and nut quality. Breeding program priorities for developing horticulturally superior cultivars are presented.

Eastern black walnut (*Juglans nigra* L.) trees produce a uniquely flavored nut that is a favorite in many Midwestern kitchens. Each year, American consumers use 2 million pounds of black walnut kernels in cookies, cakes, and ice cream products (Hammons 1998). The current level of black walnut production is supported by the collection and processing of nuts from wild walnut trees. During the fall, rural residents harvest nuts by hand and deliver the nuts to hulling and buying stations set up across the Midwest. An average of 25 million pounds of hulled seedling walnuts are purchased per year at an average price of 10 cents per pound.

The continued reliance of the black walnut industry on the hand harvest of seedling trees will not allow for the future expansion of this nut crop. The wild crop is inherently variable, with wide swings in both total production and nut quality. This unpredictability of supply undermines the industry's ability to increase utilization. Further, increasing family incomes and a continuing population shift from rural to suburban areas is slowly eroding the workforce that has traditionally harvested seedling walnuts. The future of the black walnut industry lies in the establishment of orchards of high-quality, high-yielding cultivars.

Since 'Thomas' was named as America's first black walnut cultivar in 1881 (Corsa 1896), cultivar development has proceeded haphazardly. Throughout the 20th century, black walnut enthusiasts discovered new cultivars in the wild or planted open pollinated seeds of previously named cultivars just to "see what happens". Even at this slow pace of crop development, over 700 cultivars have been named (Berhow 1962, Reid 1997a) and the percent of edible kernel has improved two-fold (seedling walnuts average 17% kernel while some cultivars consistently produce over 34% kernel). But these improvements in kernel quality have not been enough to stimulate large-scale development of black walnut orchards.

In recent years, we have initiated a program to systematically improve black walnut as a nut producing tree. We have started this process by evaluating the horticultural characteristics of existing cultivars, striving to understand the key components that determine yield and kernel quality. This work has also led us to develop key objectives for a systematic breeding effort to improve black walnut as an orchard crop.

HORTICULTURE CHARACTERISTICS OF BLACK WALNUT CULTIVARS

Many of today's black walnut cultivars have been selected based on a single trait, percent kernel (Reid 1990). This has lead to the propagation of hundreds of low-yielding, disease-susceptible cultivars that are able to produce enough nuts

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to satisfy a hobbyist's craving for easy to crack walnuts. In contrast, designing and implementing a commercial black walnut orchard will require detailed cultivar information, enabling growers to choose productive cultivars adapted to their specific growing conditions. Key cultivar traits include: leafing date, flowering dates, growth habit, disease resistance, precocity, productivity, and shelling quality.

Leafing and Flowering Dates

Black walnut trees are among the latest leafing trees in eastern deciduous forests. This late-leafing characteristic ensures emerging leaves, along with developing flowering structures, avoid late spring frosts. Temperatures below -2° C will kill emerging green tissues, destroy floral initials, and eliminate the potential for nut production. Among the cultivars in our collections, 'Davidson' is the first cultivar to break bud. In contrast, 'Thomas/Myers' initiated new growth more than three weeks after 'Davidson' (Table 1). We have also noted significant tree-to-tree variation in bud break date within each cultivar. Although we cannot document the cause of this effect at this time, we have initiated trials to determine rootstock effects on tree phenology and nut productivity.

As expected, late-leafing cultivars flowered later in the season regardless of dichogamy. The variation in flowering date was similar to the variation measured for bud break. (Table 1). The vast majority of cultivars in our collections exhibited the protogynous flowering habit (Table 1). These observations suggest that novel strategies may be needed to ensure pollination in black walnut orchards. In commercial pecan or Persian walnut orchards, adequate pollen is ensured throughout the flowering season by simply planting a protandrous cultivar and a protogynous cultivar in the same block (Grauke 1997, Hendricks and others 1998). In black walnut, providing pollen throughout the pollination season is made more difficult because of a critical lack of protandrous black walnut cultivars. To solve this problem, early-leafing protogynous cultivars could be used to pollinate late-leafing protogynous cultivars. However, at least one early-leafing protandrous cultivar must be included in the orchard to provide pollen for early-leafing protogynous clones.

Growth Habit

Several black walnut cultivars exhibit a branching habit that can be most accurately described as spur-type growth. Previous work has described this growth pattern as lateral bearing (Reid 1997);

Table 1.—Leafing date, flowering type and fruit ripening season for black walnut growing at New Franklin, MO, 2001-2003.

Cultivar	Leafing Date[1]	Flowering Type[2]	Ripening Season[3]
Beck	17.6 ± 2.1	II	mid
Christianson	21.5 ± 4.0	II	mid
Clermont	19.0 ± 5.2	II	mid
Cranz	19.3 ± 4.0	II	late
Daniel	14.6 ± 6.5	II	early
Davidson	0	II	early
Dot	22.5 ± 3.5	II	mid
Drake	17.0 ± 4.4	II	mid
Elmer Myers	18.0 ± 5.4	II	late
Emma K	5.3 ± 2.5	II	mid
Football	11.0 ± 2.1	I	early
Grundy	10.7 ± 2.3	II	late
Hay	22.0 ± 5.3	II	late
Knuvean	8.3 ± 1.2	I	early
Krouse	5.7 ± 0.6	II	late
Kwik Krop	18.3 ± 1.5	II	mid
McGinnis	5.0 ± 1.7	I	mid
Mintle	7.0 ± 1.0	II	mid
Rowher	17.3 ± 2.3	II	mid
Rupert	8.3 ± 1.5	II	late
Sarcoxie	17.0 ± 1.7	II	mid
Sauber	14.7 ± 6.0	II	early
Schessler	2.0 ± 1.1	II	early
Scrimger	16.7 ± 4.0	II	late
Sparks 127	17.0 ± 2.9	II	early
Sparks 129	17.7 ± 3.8	II	late
Sparks 147	22.7 ± 6.4	II	mid
Sparrow	16.8 ± 3.4	II	early
Stambaugh	19.7 ± 3.8	II	mid
Surprise	13.0 ± 5.1	II	late
Ten Eyck	20.3 ± 4.5	II	late
Thatcher	18.3 ± 5.8	II	late
Thomas	21.0 ± 5.8	II	late
Thomas/ Myers	22.7 ± 6.4	II	early
Victoria	15.7 ± 3.8	I	late

[1] Mean Days after Davidson ± std. dev. (Davidson average leaf burst = Apr. 12)
[2] I = protandrous, II = protogynous
[3] Ripening dates
Early = Sept. 1-14
Mid = Sept 15-28
Late = Sept. 29 - Oct 12

however, the growth and bearing habit of spur-type black walnuts is not analogous to the lateral bearing habit found in Persian walnut (*Juglans regia* L.). Lateral bearing in *J. regia* occurs when lateral shoots arise from the current season's new growth and terminate in a pistillate flower cluster (Hendricks and others 1998). This type of bearing habit has not been observed in black walnut. However, several black walnut cultivars develop short, compact branches (compressed internode lengths) along primary branches in a growing habit comparable to spur-type apples. Black walnut spurs are multi-year-old shoots that grow to a length of 8 to 12 inches. These spurs dramatically increase the number of potential fruiting sites on the tree and can spread fruiting throughout the canopy. Spur-type black walnut cultivars are listed in Table 2.

Anthracnose Susceptibility

Anthracnose is a major limiting factor to annual nut production in black walnut (Reid 1995). Although anthracnose can infect stems and fruit, leaf infections prove most damaging to tree performance. The anthracnose fungus (*Gnomonia leptostyla* [Fr.] Ces. & De Not.) can infect leaves shortly after full leaf expansion and completely defoliating the tree by mid-August (Neely 1979). Early defoliation decreases nut quality (Reid 1986) and enhances the trees natural tendency towards alternate bearing (Worley 1979).

To evaluate black walnut cultivars for anthracnose susceptibility, we rate the defoliation of fruiting shoot leaves in mid-August (expressed as a percentage of leaflets lost). By evaluating fruiting shoots only, we ensure that our assessments are made on leaves from all the same age cohort (Reid 1995). We have not found cultivars with complete resistance to this disease, but have noted wide variation in susceptibility. Among the most susceptible clones in our trials are such popular cultivars as 'Football' and 'Surprise'. In contrast, 'Sparrow' and 'Thomas' demonstrated excellent leaf retention. Initial evaluations of anthracnose susceptibility for black walnut cultivars can be found in Table 3.

Table 2.—Black Walnut cultivars exhibiting the spur-type growth habit. Data taken from Reid (1997a, 1997b).

Cultivar Exhibiting Spur-type Growth	
Beck	Kwik Krop
Cranz	McGinnis
Davidson	Rupert
Emma K	Sparks 127
Football	Sparks 147
HPC-120	STW-13
HPC-148	Surprise

Yield and Alternate Bearing

The lack of emphasis in the selection process on nut yield, especially yield of edible kernel/acre, is the primary impediment to the commercialization of black walnut. Potential black walnut growers must be confident that income from nut sales will return a fair profit for investments made in land, labor, trees, supplies, and equipment.

Our initial investigation of black walnut cultivar performance was initiated in 1987 when 21 cultivars were propagated on black walnut rootstocks in a replicated study. Trees were fertilized with nitrogen (100 lbs. N/acre/year) and anthracnose was controlled with fungicides. Nut production began 4 years after propagation but the first significant crop wasn't recorded until 1997. Yield data for these cultivars for the five year period, 1997-2001, is given in Table 4. In this young orchard, Rupert had the greatest in-shell yield but Drake produced the most kernels (Table 5). Emma K and Football exhibited perfect alternate

Table 3.—Anthracnose ratings for black walnut cultivars growing at New Franklin, MO during 2003.

Cultivar	Anthracnose Defoliation Potential[1]	Cultivar	Anthracnose Defoliation Potential[1]
Bowser	higth	Patterson	med
Crosby	low	Rupert	low
Christianson	med	Sauber	med
Clermont	med	Schessler	med
Cochrane	high	Scrimger	low
Davidson	med	Sparks 127	high
Elmer Myers	high	Sparks 147	med
Emma K	med	Sparrow	low
Football	high	Stambaugh	med
Hare	med	Surprise	high
Jackson	high	Thomas	low
Kwik Krop	med	Thomas/Myers	med
Mintle	high	Victoria	med

[1] *High > 30% leaflets defoliated by mid-August*
Med = 16-30% leaflets defoliated by mid-August
Low< 16% leaflets defoliated by mid-August

bearing, producing nuts one year followed by zero production the next year. In contrast, low yielding Cranz produced a small crop of nuts each year, while Rupert demonstrated both high yield and low alternate bearing tendency.

Nut production during this time period was comparatively low even for the highest yielding clones. The black walnut trees in this study were established at a spacing of 30 ft. x 30 ft. or 48 trees/acre. Production of 20 lbs. (a high averages yield in our trial) of hulled and dried nuts per tree would result in a yield of 960 lbs/acre. In contrast, young Persian walnut orchards (years 10-15) yield over 4000 lbs/acre of hulled and dried nuts (Hendricks 1999).

Fruit and Nut Characteristics

Each fall, black walnut enthusiasts collect nut samples of each cultivar in their planting in order to enter nut judging contests held in most Midwestern states. Nuts are weighed, cracked, and then kernels weighed to determine average nut weight and percent kernel. These basic nut quality parameters have been determined for hundreds of black walnut clones and provide much of our current knowledge base for black walnut cultivar performance. The results of 43 years of nut sample evaluation in Kansas are presented in Table 6.

Since black walnut is not marketed to the consumer as an in-shell product, large nut size has not been an important cultivar selection criterion. Ease of shelling has been and will continue to be one of the most important nut quality traits measured. Important nut characters that influence ease of shelling include shell thickness, inner wall partition thickness, and openness of kernel cavity. These characteristics are easily observed by cutting open the nut in cross section with a band saw. We are currently working on methods to quantify these nut traits.

Missing from nut evaluations are critical determinations of husk characteristics. In black

Table 4.—Yield, average yield and alternate bearing index for black walnut cultivars growing at Chetopa, KS.

	Yield (lbs./tree)						
Cultivar	1997	1998	1999	2000	2001	5 Year Average	Alternate Bearing Index[1]
Bowser	1.8	6.1	5.1	1.1	10.6	4.9	0.52
Cranz	10.8	5.5	7.2	7.1	6.8	7.5	0.12
Davidson	23.0	0.0	17.0	27.3	28.9	19.2	0.57
Drake	23.0	6.0	27.8	5.9	36.1	19.8	0.65
Dubois 8415	3.1	0.7	3.8	0.0	3.3	2.2	0.83
Emma K	2.5	0.0	8.1	0.0	13.8	4.9	1.00
Farrington	4.0	2.4	9.6	1.5	11.1	5.7	0.59
Football	24.0	0.0	22.0	0.0	13.0	11.8	1.00
Kwik Krop	2.4	0.3	6.9	0.0	3.4	2.6	0.92
McGinnis	6.0	0.8	12.1	0.0	28.3	9.4	0.91
Mintle	18.9	0.0	6.7	1.5	16.3	8.7	0.87
Rupert	30.9	11.8	19.2	23.8	27.4	22.6	0.22
Scrimger	2.2	2.0	8.7	2.5	15.6	6.2	0.49
Sparks 127	10.0	0.0	4.2	0.9	5.4	4.1	0.84
Sparks 147	2.7	3.4	6.9	0.6	2.4	3.2	0.47
Sparks 177	21.6	7.8	9.8	15.8	1.4	11.3	0.41
Sparrow	15.2	4.2	24.4	7.6	28.2	15.9	0.59
Stabler	4.1	7.6	20.5	0.0	12.4	8.9	0.69
Surprise	7.5	16.1	12.6	4.3	6.2	9.3	0.29
Vander Sloot	12.7	8.6	20.1	1.8	14.5	11.5	0.55
Victoria	22.5	2.3	10.0	0.3	5.4	8.1	0.82

[1] *Alternate bearing index =* $1/(n-1)\ \Sigma\ |(y_n - y_{n-1})/(y_n + y_{n-1})|$*, where y= yield and n=year.*

Table 5.—Average yield (1997-2001), percent kernel, and kernel yield for black walnut cultivars growing at Chetopa, KS.

Cultivar	Yield (lbs./tree)	% Kernel	Kernel (lbs./tree)
Bowser	4.9	34.03	1.67
Cranz	7.5	32.87	2.47
Davidson	19.2	27.45	5.27
Drake	19.8	30.97	6.13
Dubois 8415	2.2	29.10	0.64
Emma K	4.9	34.28	1.68
Farrington	5.7	32.13	1.83
Football	11.8	32.62	3.85
Kwik Krop	2.6	31.03	0.81
McGinnis	9.4	32.24	3.03
Mintlev	8.7	29.86	2.60
Rupert	22.6	25.55	5.77
Scrimger	6.2	30.94	1.92
Sparks 127	4.1	32.58	1.34
Sparks 147	3.2	38.04	1.22
Sparks 177	11.3	33.46	3.78
Sparrow	15.9	31.51	5.01
Stabler	8.9	30.32	2.70
Surprise	9.3	32.63	3.03
Vander Sloot	11.5	25.70	2.96
Victoria	8.1	24.93	2.02

walnut, kernel color is strongly affected by the length of time the husk remains on the nut following fruit ripening (Chase 1941). As the husk begins to soften (break down), black-staining alkaloids are released from the husk and soak through the shell to darken the nut meat and change the flavor of the nut. This results in the 'strong' flavor of which most consumers of black walnut are familiar. Removing the husk and washing the nut as soon as the fruit becomes ripe results in walnut kernels that are lighter in color and milder flavored. Uniformity of fruit ripening has a major impact on kernel quality. Since most walnuts are harvested following a single tree shaking, trees with long ripening periods will appear to produce kernels that vary widely in color. This stems from the fact that, at the time of harvest, nuts are collected at varying stages of husk ripening and hence varying stages of kernel staining.

Black walnut husks are indehiscent and must be removed mechanically following harvest. However, it has been noted that some cultivars are easier to hull than others. We have observed two types of walnuts: cultivars that could be termed 'cling-stone', where the husk is tightly held by the shell and cultivars that are 'free-stone', where the husk is loosely held or separated from the nut shell at

Table 6.—Average nut weight and percent kernel of black walnut cultivar samples entered in the Kansas Growers Association Annual Nut Show from 1959-2001.

	Nut Weight (g)		% Kernel	
Cultivar	Mean	Std. Deviation	Mean	Std. Deviation
Beck	15.87	0.23	27.97	1.51
Bowser	15.51	1.42	32.27	3.93
Clermont	16.40	5.70	30.27	3.32
Cochrane	14.05	0.42	32.47	1.94
Cranz	14.18	1.51	30.46	3.62
Davidson	22.31	1.90	26.55	1.57
Drake	19.31	1.82	30.09	2.44
Emma K	16.32	2.57	34.57	1.91
Eureka	15.86	1.96	25.94	0.05
Farrington	19.03	5.93	26.78	5.20
Football	20.29	2.66	29.96	2.30
Hare	21.10	2.31	27.21	1.66
Jackson	14.29	1.85	35.43	1.25
Kwik Krop	17.10	2.89	30.55	2.50
McGinnis	16.66	0.12	31.19	2.90
Mintle	16.06	1.61	30.99	2.30
Myers	14.17	2.53	25.90	8.03
Ogden	19.71	5.93	21.24	5.34
Ohio	16.52	2.21	27.19	4.04
Peanut	19.53	0.32	26.08	5.20
Perry	19.55	1.82	27.41	1.20
Rowher	22.38	3.13	24.30	1.07
Rupert	18.29	1.54	25.12	0.91
Sauber	15.11	2.27	32.03	2.57
Scrimger	19.11	2.56	29.44	2.22
Sol	19.34	2.37	24.13	1.46
Sparks 127	15.00	2.91	32.64	2.99
Sparks 147	16.69	1.51	36.45	4.23
Sparks 177	20.90	2.15	33.07	1.60
Sparrow	18.59	2.25	29.92	2.07
Stabler	16.97	2.91	25.40	4.94
Stangle	18.98	3.30	27.07	3.34
Stark	18.82	3.11	26.56	3.89
Surprise	20.28	2.27	33.20	2.15
Thomas	21.79	4.88	24.39	4.54
Tom Boy	21.66	1.02	27.38	2.15
Vander Sloot	24.35	2.53	27.54	1.77
Victoria	17.73	3.22	24.37	3.60

ripening. We are in the process of collecting data on these important husk characteristics.

SETTING PRIORITIES FOR A BLACK WALNUT BREEDING PROGRAM

Black walnut remains an emerging crop. Will black walnut cultivars be found with the yield potential to cover the high costs of harvest, hulling, washing, and drying nuts? As we work with this crop, we may discover new cultural techniques that promote yield, but a systematic genetic improvement program holds the greatest potential for developing cultivars able to sustain a commercial walnut orchard industry.

Many important genetic traits can be found in today's black walnut cultivars. By producing nuts that average 38% kernel, 'Sparks 147' demonstrates that black walnut can be pushed towards a truly thin shelled nut. Many cultivars produce walnuts on spurs increasing the potential nut bearing surface of the tree. Still other cultivars seem less susceptible to anthracnose. The genetic variation necessary for an effective breeding program is available, but what are our genetic goals?

Goals for Improving Yield

Almost every walnut enthusiast has seen a walnut tree so heavily laden with fruit that the limbs are breaking. Crack open some nuts from one of these over-producing trees and you will find poorly filled kernels. In addition, the tree will not bear another nut crop for at least two years. Do these common observations indicate that black walnut trees are already producing near their genetic limit? We think not.

Black walnut trees expend a huge amount for biological energy to produce both husk and shell. The husk is a waste product that stains many things it touches black. While the shell has some commercial value (Hammons 1998), its value has a minimal impact on the economics of a walnut orchard. In breeding walnuts for nut production, reducing the tree's investment in husk and shell should allow more energy to be directed towards kernel production. The advantage of this strategy can be easily seen by comparing the husk and shell of a modern Persian walnut cultivar to that of a black walnut cultivar, then comparing the yields of these two species (see above). The hybridization of *J. regia* with *J. nigra* has been recorded with few positive results (McKay 1971). Although additional hybridization work may be warranted, we feel that we can meet our objectives of minimal husk and thin shells within *J. nigra*.

Preliminary work with different seed sources for rootstock trees seems to indicate that rootstock may have a dramatic influence on scion performance. We have already observed a rootstock effect on leafing date (above). We have yet to document the impact rootstock has on yield but trials are in place. We are also interested in the potential of interspecific hybrids for rootstocks in black walnut orchards.

Selecting trees that develop fruiting spurs at a young age will enhance precocity, increasing yield during the establishment phase of a walnut orchard. But maintaining the fruitfulness of spurs on mature trees may be the key to maximizing yield. Optimum light penetration into the tree canopy is critical for the stimulation of flowering on spurs (Van Sambeek 1998). By selecting trees exhibiting open tree architecture, we can ensure nut production throughout the canopy.

We have already discussed the critical lack of protandrous black walnut cultivars. Is a lack of early shedding pollen in the orchard contributing to low yields? For some early leafing cultivars, lack of pollen may be a problem; however, we have not documented this or other potential pollination problems in black walnut. In any case, the development of protandrous cultivars should be important to the commercial success of this crop.

Goals for Improving Disease Resistance

As mentioned earlier, anthracnose is a major limiting factor to fruit production in black walnut. Although immunity to this disease has not been identified, we will strive to incorporate some level of natural defense against this disease. Anthracnose can be controlled with well-timed fungicide applications; however, the propagation of extremely susceptible clones will only result in increasing production costs (more fungicide applications) for nut producers. All seedlings in the breeding program will be screened for anthracnose susceptibility. Seedlings demonstrating severe susceptibility to the disease will be culled.

Goals for Improving Nut and Kernel Quality

'Thomas', our oldest black walnut cultivar, averages 24% kernel. Today, we hardly consider planting a new walnut cultivar unless it produces at least 30% edible kernel. Several cultivars regularly produce nuts containing over 35% nut meat. The genetic improvement of percent kernel in black walnut is the one significant advancement made thus far in the evolution of this tree as an orchard crop. But additional improvements can be made. Our thinnest shelled walnuts are only one or two generation removed from wild ancestors. With controlled crosses and additional selection pressure we will strive to develop walnuts with over 40% kernel.

Kernel quality is heavily influenced by husk characteristics. Uniformity in fruit ripening is critical for harvesting uniformly light colored kernels. Ease of hull removal enhances a producer's ability to remove all remnants of kernel-staining hull from the nut. Yet to be discovered are the negative husk characteristics that promote dark veins in the kernel integument. As we continue to work with the collection of cultivars we currently have available, recording husk parameters will provide us with the valuable information we will need to incorporate husk traits into the breeding program.

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