Black Walnut: A Nut Crop for the Midwestern United States

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Abstract. Eastern black walnut (*Juglans nigra* L.), is a native tree species valued both for its timber and nuts. Individual trees require excellent soils with adequate moisture for maximum wood and nut productivity. The vast majority of black walnut nutmeat production is centered in the western part of the species' native range and is predominantly derived from wild, unimproved sources. Historically, the size of this crop has ranged from 4.5 to 15.9 million kilograms (fresh weight, without hull) with less than 1% obtained from improved cultivars. Alternate bearing is common in this species, primarily as a result of susceptibility to walnut anthracnose *Gnomonia leptostyla* (Fr.) Ces. & De Not. Significant reductions in nut productivity caused by walnut curculio (*Conotrachelus retentus* Say) are common for unimproved, wild trees. Based on a collection of 65 nut cultivars established by the University of Missouri, black walnut exhibits significant genetic variation for a range of commercially important nut traits, including precocity, percent kernel, nut bearing habit, anthracnose tolerance, season length, and yield efficiency. Exploiting this variation through traditional plant breeding techniques will result in new, improved varieties in the future. Defining improved cultural practices that will significantly impact yield and nut quality remains an area of active investigation. Such knowledge will need to be combined with improved cultivars that are well adapted to local growing conditions to ensure the commercial success of this species over the long run.

CURRENT LIMITATIONS ON BLACK WALNUT PRODUCTION

In 1955, there were 10 nut cracking plants specializing in black walnut nutmeat production, capable of processing 27.2 million kilograms of dried in-shell nuts, yielding 3.3 million kilograms of edible nutmeats (12% yield) (Zarger, 1969). However, the exclusive reliance on wild, unimproved sources has led to a precipitous decrease in the number of cracking plants over the past 50 years. It is likely that this decline was the result of several market-driven forces, including ever-increasing transportation costs and variable recovery rates of edible nutmeats resulting from scaling effects associated with different sized plants. However, continued reliance on a resource prone to extreme fluctuations as a result of alternate bearing undoubtedly contributed to the decrease in the number of black walnut cracking plants. Currently, Hammons Products Company located in Stockton, MO, remains the sole, large-scale production company of wild black walnut nutmeats and shell products in the United States.

Historically, the size of the annual crop purchased by Hammons Products Company has ranged from 4.5 to 15.9 million kilograms (hulled, fresh weight basis). Nutmeat yields derived from this extensive wild crop averaged

7% from 1999 through 2008. Additionally, black walnut shell products (7.4 million kg/year) are also used in a wide variety of industrial applications. Although over 66% of this crop normally comes from Missouri, the remaining quantity is commonly purchased from individuals through a system of 250 hulling stations distributed across 17 different states (B. Hammons, personal communication). Without question, the greatest constraint associated with the growth of black walnut as a nut crop for the midwestern United States can be directly tied to the alternate bearing tendency of the wild crop, which is exacerbated by walnut anthracnose [*Gnomonia leptostyla* (Fr.) Ces. & De Not]. In addition, local nut production levels can be greatly reduced by walnut curculio (*Conotrachelus retentus* Say). Although both of these pest problems can be readily controlled in orchard settings (Reid et al., 2009), they have the potential to significantly reduce the size of the wild crop in certain years.

In contrast to the Hammons Products Company business model, a Nebraska-based cooperative called Heartland Nuts and More markets nutmeats derived solely from improved black walnut cultivars. This cooperative includes 46 growers located in Iowa, Kansas, Missouri, and Nebraska. Current production levels are limited as a result of a lack of mature orchard acreage but are expected to increase dramatically as additional orchards come into production. In 2008, this cooperative purchased 9100 kg (dried, in-shell) nuts yielding a minimum of 25% edible kernel, which were primarily marketed to local food outlets as well as through internet sales (L. Martin, personal communication).

POTENTIAL FOR EXPANDED PRODUCTION

Kernel recovery rates from wild sources normally average 12% to 13% (Zarger et al., 1969), whereas improved nut cultivars can yield over 30% kernel (Reid et al., 2004).

Currently, all improved cultivars used to establish black walnut orchards were originally selected by individual enthusiasts rather than derived from any formal breeding program. In the vast majority of cases, these trees were originally selected solely for high kernel percentage rather than nut yield. As a result, many early named selections are now considered obsolete (Reid, 1997a).

Reid et al. (2004) suggested a list of horticultural traits that should be included in any black walnut breeding program focused on developing new nut cultivars, including an emphasis on leafing and flowering phenology, nut bearing habit, susceptibility to anthracnose, and nut yield as a function of both tree size and alternate bearing tendency. Although these authors concluded that an improved understanding and acceptance of newly developed cultural and harvesting practices will certainly contribute to overall nut yields, the long-term success of a commercial black walnut industry will ultimately require the development of new cultivars that exhibit improved yield, disease resistance, and kernel quality.

In response to this need, a breeding program was initiated at the University of Missouri in 2000 with the goal of developing improved nut cultivars for use in agroforestry-based plantings (Coggeshall, 2002). The initial breeding population was comprised of 84 named cultivars established in a series of replicated clonal repositories beginning in 1996. Standardized phenological descriptors (IPGRI, 1994), originally developed for Persian walnuts (*J. regia* L.), have been used to characterize this Missouri collection as well as an older collection of black walnut nut cultivars maintained by the University of Nebraska and Kansas State University (Morrissey and Gustafson, 1989; Reid et al., 2004; Warmund and Coggeshall, 2010). Recently, microsatellite (simple sequence repeat) markers were used to further characterize the collection of nut cultivars at the University of Missouri (Coggeshall and Woeste, 2010). Results suggested that

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32% of the 84 different cultivars represented in this collection were actually mislabeled. Although disappointing, these results should not be considered to be surprising because the vast majority of these accessions was obtained from individual growers rather than commercial sources.

The cultivars included in this collection exhibit significant genetic variation for a range of commercially important nut traits, including precocity, percent kernel, nut bearing habit, anthracnose tolerance, season length, and yield efficiency. Based on phenological and morphological descriptor data, a series of control pollinated seedlings were produced beginning in 2002. Pistillate flowering and fruiting began in the fifth leaf. Ongoing evaluations of this pedigreed material revealed consistent differences in pistillate flower/nut ratios among the most precocious individual trees as well as differential nut bearing habit and measures of yield efficiency (Coggeshall, 2007).

Several studies have reported on the adaptability of black walnut cultivars in the midwestern United States in terms of leafing and flowering phenology as well as season length. Leafing date can extend over a 5-week period beginning in mid-April (Coggeshall and Woeste, 2010; Reid et al., 2004; Warmund and Coggeshall, 2010). Black walnuts are heterodichogamous in terms of flowering habit. Interestingly, the vast majority of black walnut cultivars evaluated thus far in Kansas (Reid et al., 2004), Missouri (Warmund and Coggeshall, 2010), and Nebraska (Gustafson and Morrissey, 1989) tend to exhibit a protogynous flowering habit, which can lead to a lack of desirable pollen in orchards as a result of a lack of available protandrous clones. As an alternative, a number of early-leafing, protogynous cultivars could be included to effectively pollinate other late-leafing protogynous cultivars (Reid et al., 2004). In Missouri, such early-leafing protogynous cultivars are readily pollinated by wild trees (Coggeshall, unpublished data). Season length, calculated as the number of days between mean pistillate bloom and harvest date, ranged from 118 to 168 d for a collection of 39 different nut cultivars in central Missouri (Warmund and Coggeshall, 2010). Furthermore, a model that explained patterns of variation in spring budbreak date for 20 of these same cultivars over four growing seasons was reported by Warmund et al. (2009c). The number of chilling units ranged from less than 1400 to 1625, depending on cultivar.

In terms of nut bearing habit, those black walnut cultivars that exhibit a tendency to produce nuts on short, 2-year-old lateral shoots are more precocious and productive (Coggeshall, 2007). However, a more accurate description of this nut bearing tendency would be that they are borne on short, compact branches, similar to spur-bearing apple varieties (Reid, 1997b). This type of nut bearing habit has also been shown to occur within a collection of control pollinated seedling offspring derived from spur-bearing parents. Such seedlings are also precocious, bearing nuts as early as the fourth leaf (Coggeshall, 2007).

Susceptibility to walnut anthracnose caused by *Gnomonia leptostyla* (Fr.) Ces. & De Not. is considered to be the most important factor affecting consistent, annual nut production in black walnut (Reid, 1995). Susceptible trees can become completely defoliated by August, resulting in poor kernel quality as well as an increase in a natural inclination of some trees to exhibit alternate bearing (Reid et al., 2004). Although there is a tendency for susceptible trees to alternate bear, this relationship appears to be independent of nut maturity date (Reid et al., 2004) in contrast to Persian walnut in which early-maturing varieties tend to be less prone to alternate bearing. In addition to susceptibility to anthracnose, and its linkage to alternate bearing, the productivity of specific black walnut cultivars is a function of yield efficiency, because the majority was first selected solely on the basis of kernel percent rather than yield. For example, cumulative nut yields, expressed as the total number of nuts produced per tree multiplied by the mean number of nuts per kilogram, ranged from 7.1 to 72.5 kg per tree in a 13-year-old cultivar collection of 20 black walnut cultivars in Missouri (Coggeshall and Warmund, 2009).

DESIGNING NEW ORCHARDS

Black walnut orchards are established using either container-grown grafted trees or field grafted stock. The importance of rootstock origins on initial survival and growth of such grafted trees has been investigated, but longer-term studies are needed. Although the origin of rootstock had no effect on either third-year survival or growth rates at two Missouri plantings (Coggeshall et al., 2003), rootstock source did influence second- and third-year survival rates of four plantings established in Arkansas and Missouri (Thomas et al., 2008). These results suggest that a number of factors may contribute to the successful establishment of black walnut orchards in the midwestern United States, including the selection of specific rootstocks to use for a chosen scion source.

Current spacing recommendations for new black walnut orchards are a 9.1 × 9.1-m square layout with one cultivar established in each row to facilitate harvesting operations. This initial spacing will allow for two successive thinnings, resulting in 30 trees per hectare at 18.3 × 18.3-m spacing (Reid et al., 2009). The timing of the first thinning will be dependent on site quality as well as cultivar. In Missouri, rates of crown spread ranged from 0.58 to 0.85 m per year, depending on cultivar, which suggests that crown closure in a 9.1 × 9.1-m orchard would begin in 14 to 19 years (Coggeshall and Warmund, 2009). Ultimately, it is anticipated that production levels for a mature black walnut orchards should equal 2 t·ha⁻¹ per year (Reid, 1997b).

FUTURE OUTLOOK

Black walnuts have an indehiscent husk and kernel maturity commonly occurs before natural nut fall. As a result, the actual harvest

date can significantly impact kernel quality, because any progressive husk maturity over time will darken the fully mature kernels and may ultimately affect kernel taste. Harvest dates are commonly determined by sampling husk firmness, usually by hand. However, such assessments can be prone to error. To determine the effects of husk softness on kernel color for multiple cultivars, Warmund and Coggeshall (2006) correlated durometer data, which evaluated husk softness (elasticity), with kernel color using a handheld spectrophotometer for five black walnut cultivars harvested over four collection dates. Each cultivar exhibited a specific range of durometer values that were correlated with kernel color, and these values decreased over time. It is suggested that this approach of quantifying husk firmness, as a function of nut maturity, using a durometer will result in more efficient harvesting operations and improved, consistent kernel quality in black walnut orchards in the future.

Black walnut kernel color has also been associated with taste perception with darker kernels considered as being less desirable to customers (Warmund et al., 2009a). Darkened kernels are a function of delayed harvest date and although they can be excised using modern color sorting technology, there will be economic consequences associated with such kernel heterogeneity. Properly timed harvesting, followed by prompt husk removal and nut washing, will guarantee the highest financial return for the grower.

Although defining the proper timing and handling of black walnut kernels to maximize quality is critical to the ultimate success of this species as a nut crop for the midwestern United States, the question of promoting such a product in new markets will be of great importance in the future, especially in contrast to the current market dominance held by the Persian walnut industry in California. Recently, a total of 22 kernel attributes of black walnut and Persian walnut were contrasted by Warmund et al. (2009b), who found that 20 such characteristics were common to both black walnut and Persian walnut. These results suggest that kernels of specific black walnut cultivars are readily distinguishable from Persian walnuts in terms of sweetness and aroma. It is expected that these attributes should be used to promote black walnut kernels in the future.

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