

NUT PRODUCTION IN RESPONSE TO THINNING AND FERTILIZATION FOR PLANTED BLACK WALNUT

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Abstract.—Nut production from nursery-run black walnuts grown on 225 acres at the Hammons Products Company's Sho-Neff Black Walnut Farm in Stockton, MO, was evaluated from 1995 to 2010 to determine if nut production increased after thinning and fertilization in 2001. The farm consists of 11 upland and 10 bottomland plantings on sites ranging from unsuitable to well suited for growth of walnut. All 21 stands were thinned in 2001, removing about one-third of the trees, and fertilized with 60, 20, and 60 pounds per acre of nitrogen, phosphorus, and potassium, respectively. Nine stands were limed to raise pH to 5.5 or higher. Five stands received an additional spring and fall application of nitrogen. Milled walnut shells and husk waste were periodically applied to 11 stands. Hay was harvested between rows 40 feet apart both before and after thinning and fertilization. Nut production increased on average 20 pounds per acre with one-third fewer trees over the 9-year post-treatment period compared to the 7-year pretreatment period. The modest gain in nut production suggests that competition between trees and low soil nutrients were not the major factors limiting nut production. These results cause us to wonder: can a grower expect early economic returns from nut production on an investment made in the culture of young black walnut from nursery-run or unimproved seedlings?

From the founding of the Walnut Council in 1970 to now, many acres of planted nursery-run seedlings of black walnut (*Juglans nigra* L.) have reached nut-bearing age and size, but few of these trees are producing substantial nut crops. While the species is well known for its desirable wood characteristics exhibited in furniture, paneling, lumber, and other products, nut production on unimproved walnut remains a value-added consideration as an early return on the investment. Suspected reasons for low production include unsuitable soils, poor cultural treatments, environmental factors, and genetics (Ponder et al. 2001). Most stands are not thinned

sufficiently to encourage development of large crowns that create the branching structure needed to support and encourage large nut crops. Also confounding nut production is the irregular bearing pattern that is typical of many fruit and nut trees (Sparks 1974). The remedy for this problem is believed to be linked to adequate carbohydrate reserves during the growing season (Sparks 1974, Van Sambeek 1998).

While much more attention has been directed to increasing the growth of black walnut than to increasing nut production, a few authors report that nut crop production can be increased by fertilization and other treatments (Garrett et al. 1991, Garrett and Kurtz 1983, Jones et al. 1995, Ponder 1976). The Hammons Products Company, using seedlings grown from nuts of unimproved or wild trees, developed one of the first eastern black walnut farms in the United States, named Sho-Neff Black Walnut Farm in honor of the farm's previous owners. The farm is being managed to produce black walnut veneer, lumber, and nuts. In

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2001, the company tried a number of treatments to increase nut production including thinning, liming, fertilization, and application of mill and husk waste (Ponder et al. 2001). In this paper, we compare black walnut nut production before and after the application of various combinations of these treatments within 21 walnut plantings on the farm.

METHODS AND MATERIALS

The Sho-Neff Black Walnut Farm is located in Cedar County in southwest Missouri and is owned and operated by the Hammons Products Company of Stockton, MO (37 N latitude, 94 W longitude). The farm is bordered on the north by Cedar Creek and partly on the east by the Sac River. Some areas of the farm are influenced by lowland conditions, while other areas are on uplands. Soils are deep to very deep, nearly level, moderately sloping, and range from poorly, to moderately well drained, to well drained. These soils are fine-loamy, mixed, mesic, and were derived primarily from acid sandstone. Overall, soils had a mean pH of 6.4, cation exchange capacity (CEC) of 11.2, 64 pounds per acre of available phosphorus (P), and 179 pounds per acre of available potassium (K). Since the early 1970s, the farm has implemented several soil conservation improvements including the application of lime, soil placement, and drainage way construction.

The farm, which includes acreage in mature forest, was divided into 25 stands based primarily on landscape, drainage, and vegetation (Fig. 1). This was done before the black walnut soil suitability (BWSI) ratings were available on the Web Soil Survey (Natural Resource Conservation Service (NRCS) state offices). Wallace and Young (2008) described in detail the development and parameterization of this computer model for assessing walnut suitability using the properties assigned to the soils as mapped within the NRCS soils database. BWSI ranges from well suited to unsuited across the 11 upland stand (stands 16 to 25) and 10 bottomland stands (stands 1 to 12).

Beginning in 1975 and continuing over several years, the farm was planted to eastern black walnut using bare-root seedlings obtained from the Missouri Department of Conservation nursery in Licking, MO. The seedlings were planted in rows spaced 40 feet apart. Within-row spacings were 6, 10, or 20 feet between planted trees. During the first few years after planting, crops of soybeans, wheat, or milo were planted annually between rows. After several years of row cropping, many of the alleys were planted to red clover and grasses including timothy (*Phleum pratense*), tall fescue (*Festuca arundinacea*), and orchard grass (*Dactylis glomerata*) for hay production. Weeds within rows were controlled with glyphosate (N-(phosphonomethyl) glycine) and simazine (6-chloro-N', N'-diethyl-1, 3, 5-triazine-2, 4-diamine) applied annually in 5-foot-wide bands along both sides of the row using a tractor-drawn sprayer. Lateral branch pruning was done periodically over the years up to 12 feet or higher depending on the perceived tree quality.

Beginning in 1995, nuts were harvested manually from each stand and mechanically husked before determining green hulled weight. After nut production began to decline, thinning and fertilization treatments were initiated in the fall of 2000 and during 2001 within all stands, along with various combinations of liming, split application of fertilizers, and application of husk and mill wastes (Table 1). The treatments were not designed and applied as planned research and are not ideally suited to statistically test for increased nut production. The treatments did give us an opportunity to provide additional insights on the effects of these cultural practices over a large number of acres planted to the species on a range of sites ranging from well suited to unsuitable for growth of walnut.

Thinning removed about one-third of the trees and the stumps were ground in place. Soils were tested and nine stands were limed according to recommendation for growing soybean and corn as prescribed by



Figure 1.—Aerial photo of Sho-Neff Black Walnut Farm showing location of bottomland plantings (1 to 12) and upland plantings (16 to 25) with Cedar Creek along the north side (top) and the Sac River along the east side.

the University of Missouri Soil and Plant Testing Laboratory. Fertilizer (NPK) was broadcast applied in August of 2001 to all 21 walnut stands. Nitrogen, P, and K were applied at 60, 20, and 60 pounds per acre, respectively. In addition, a 50:50 split application of 120 pounds per acre of N as ammonium nitrate was applied to five stands in February and September 2001. Milled walnut shell and husk wastes were applied to 14 stands at rates from 0.2 to 11 tons per acre

(Table 1). The nutrient content of the walnut mill and husk waste was not determined before each application, except on stand 17. For stand 17, NPK concentrations of mill and husk wastes were 2.4 to 2.7 percent, 0.3 to 0.4 percent, and 1.0 to 1.2 percent, respectively. Past observations of pastures in areas where walnut wastes were applied showed no visual phytotoxicity and were greener than in areas where wastes were not applied.

Table 1.—Cultural treatments applied in 2001 to 11 bottomland and 10 upland walnut stands on the Hammons Products Company's Sho-Neff Black Walnut Farm located near Stockton, MO.

Position and stand	Acres	BWSI ^a	Treatments				
			Thinned ^b	Fertilized ^c	Limed ^d	Split N ^e	Mill wastes ^f (tons/ac)
Bottomland							
1	3.7	Well	X	X			11.2
2	8.7	Well	X	X	X		
3	6.4	Well	X	X			
4	13.4	Unsuited	X	X	X		0.2
5	11.9	Unsuited	X	X			2.6
6	6.6	Unsuited	X	X			5.2
7	41.6	Unsuited	X	X	X		3.1
8	9.2	Unsuited	X	X	X		2.7
10	35.6	Unsuited	X	X	X		0.2
11	23.1	Well	X	X		X	
12	15.6	Well	X	X	X	X	
Upland							
16A	11.1	Somewhat	X	X			7.7
16B	3.4	Somewhat	X	X			4.6
17	5.9	Somewhat	X	X			7.1
19	5.8	Poorly	X	X		X	
20	3.0	Poorly	X	X	X	X	2.4
21	8.4	Poorly	X	X	X		4.0
22	10.4	Poorly	X	X			
23	33.4	Moderate	X	X		X	0.8
24	5.0	Moderate	X	X	X		9.5
25	8.3	Somewhat	X	X			

^a Black walnut soil suitability index rating (Natural Resources Conservation Service).

^b Approximately one-third of all trees were removed in fall 2000 or spring 2001.

^c Fertilizer was applied at a rate of 60, 20, and 60 pounds per acre NPK in August 2001.

^d Lime was applied to adjust pH to 5.5 or higher in August 2001.

^e Split application of 60 pounds N per acre applied in February and again in September 2001.

^f Tons per acre of milled shell and husk wastes applied during 2001.

Because there was no control available to compare treatments, prethinning nut production data were compared to post-thinning nut production data for this report. Thus, nut data were designated as “before or pre” and “after or post” treatments. Years 1995 through 2001 (flowers for 2001 were initiated during the 2000 growing season) were considered pretreatment and years 2002 through 2006 as post-treatment for statistical analyses. Annual nut production data during the two periods were compared using repeated measures ANOVA (SAS Institute, Cary, NC) and differences between annual nut crops were tested for significance using the Tukey-Kramer method ($\alpha = 0.05$). Nut production for stands receiving lime,

the additional 120 pounds of N, and mill wastes were compared to stands not receiving the respective treatment (Table 1) by analysis of variance using PROC GLM procedure in SAS Version 8.2 (SAS Institute). Tukey's test for mean separation was used to identify significant differences ($\alpha = 0.05$).

RESULTS

Annual nut production from 1995 to 2010 was highest in 1997 and very low in 1998 and then low again in 2004, 2007, and 2010 (Fig. 2). The erratic bearing pattern is relatively consistent for both bottomland and upland stands. Sparks (1974) suggested that wild

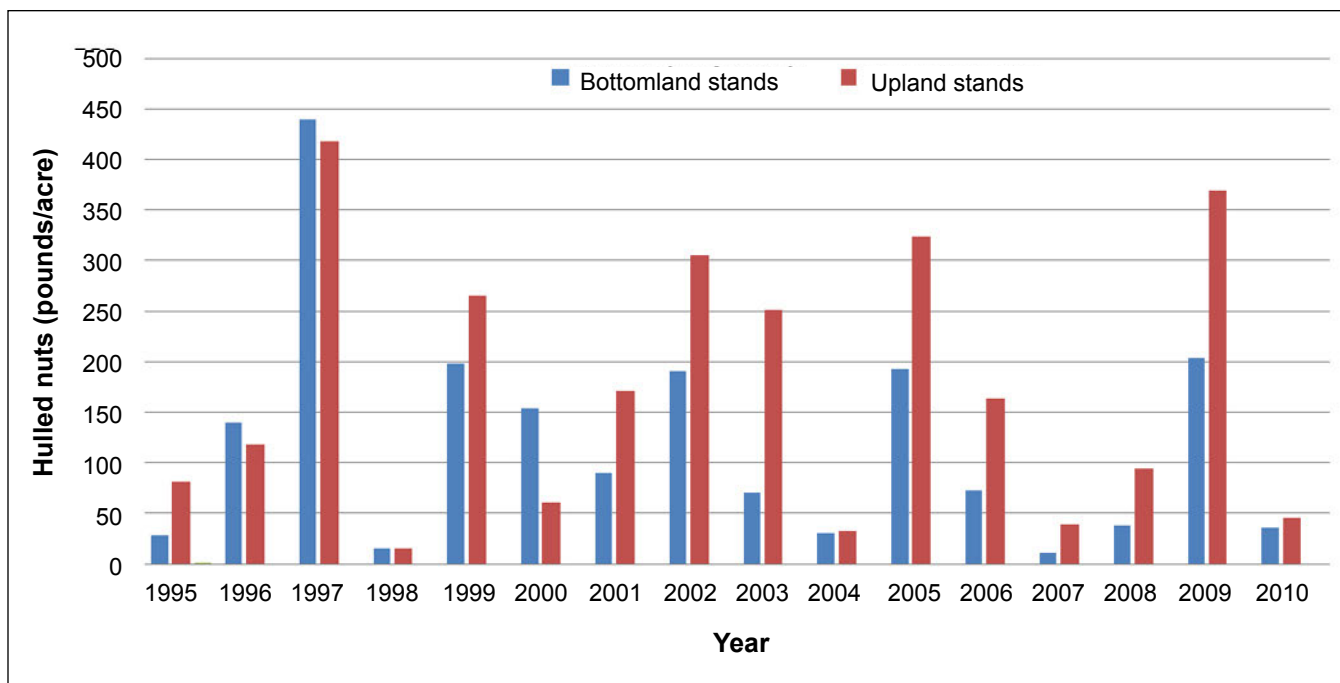


Figure 2.—Mean annual hulled nut weight per acre for bottomland and upland stands during the pretreatment years (1995-2001) and post-treatment years (2002-2010) when most stands had one-third fewer trees.

trees usually develop a bearing pattern demonstrated by a high bearing year followed by one or more low bearing years before production increases. The trend for decreased nut production of 400 to 450 pounds of hulled nuts per acre in 1997 prompted the decision to thin the stands and apply lime, nitrogen, and/or mill wastes. The lack of experimental design in the application of the treatments makes it difficult to separate causal effects on nut production variation. But there appears to be a relationship between position on the landscape (bottomland versus upland) and nut production. For simplicity, portions or all of stands 1 through 12 are considered bottomland while stands 16 through 25 are considered upland. Figure 2 suggests these treatments failed to substantially increase nut production although there are interesting differences between the response in the bottomland and upland stands.

Dividing the nut production data from 1995 through 2010 into before- and after-treatment periods meant that there were 7 years of pretreatment (1995-2001) data and 9 years of post-treatment (2002-2010) data with approximately one-third fewer trees. Mean nut

production for the pretreatment period (1995 to 2001) for all stands was 150 pounds of freshly hulled nuts per acre compared to 170 pounds of freshly hulled nuts for post-treatment years (2002 to 2010) after thinning and application of 60 pounds of nitrogen per acre in 2001.

Nut production response to thinning and fertilization did vary by stands (Fig. 3). The top nut producing stands after applying treatments were consistently on upland soils in the southwest part of the farm while the converse was true during the pretreatment period. Although both have soils 60 inches or more in depth, bottomland stands 11 and 12 have soils with an average of 0.20 to 0.24 inches of available water per inch of soil while the upland stands 2 and 3 have an average of 0.18 to 0.20 inches of available water per inch of soil according to the Cedar County soil map. We must note, however, that some of the soils in both the upland and bottomland stands are not well drained and are less than ideal for growing black walnut (Table 1). Above average annual precipitation in many of the post-treatment years may have restricted oxygen movement in the poorly drained bottomland soils

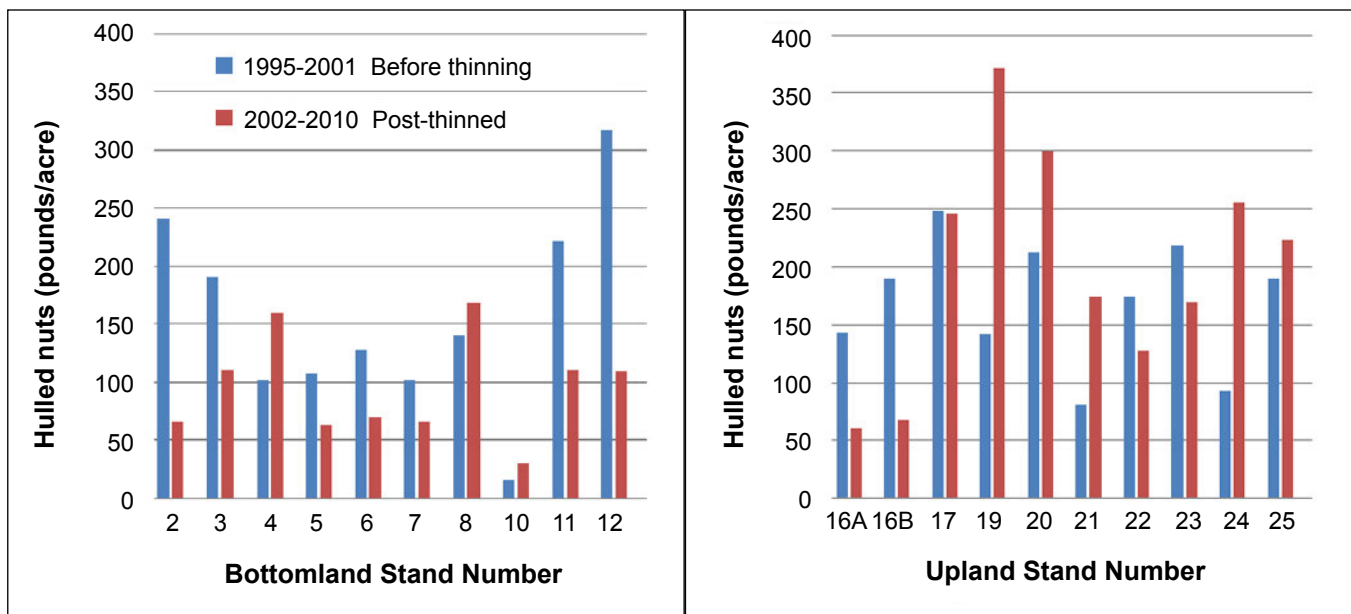


Figure 3.—Average annual hulled nut production for the 6 years before thinning and fertilization and the subsequent 9 years for 10 bottomland and 10 upland stands.

and provided trees on the upland with adequate soil moisture during the growing season, which cannot be stored in these soils. In addition, trees in stands along Cedar Creek and the Sac River, especially areas 11 and 12, were taller, larger in diameter, and had crown closure within row much earlier than trees in upland areas (James E. Jones, pers. commun., former Vice President, Hammons Products Company, Stockton, MO). Presumably tree-to-tree competition was still limiting nut production in these stands during the post-treatment period.

The stands that produced a crop each year also changed. Stands 11, 12, 17, 22, 23, and 25 were among stands producing a crop in 4 or more of the 7 years before treatment application. After treatment, however, only stands 17, 23, and 25 continued to consistently produce nut crops. The new stands now regularly producing nuts crops were 8, 19, 20, and 21.

Mean annual nut production over the 16-year period varied little when stands were grouped into the five black walnut suitability index values except for the unsuited classification where stands averaged only 84 pounds per acre annually. Plantings in the other

BWSI classes ranged from 171 pounds per acre on land somewhat suited to 188 pounds per acre on land poorly and moderately suited for growth of walnut,

In August 2001, about 2.3 tons of lime was applied per acre to nine stands. Before application of lime, these stands tended to have lower nut production than the 15 stands that did not receive lime in 2001 (Fig. 4). There is a trend for liming in 2001 when the flowers for the 2002 nut crop were initiated to have reduced nut production in 2002 but not in subsequent years. Statistically, the effect of liming on post-treatment nut production (2002 to 2006) was insignificant in part due to the wide variability between stands and annual nut crops.

An additional application of 120 pounds of N as ammonium nitrate in a 50:50 spring:fall split in 2001 was tried because fall application of N has been shown to increase female flower initiation. Statistically there were no post-treatment differences (2002 to 2006) in annual nut production for the 5 stands receiving three applications of nitrogen and 18 stands that received only 60 pounds of nitrogen. Before the split application of nitrogen, there was a trend for these five

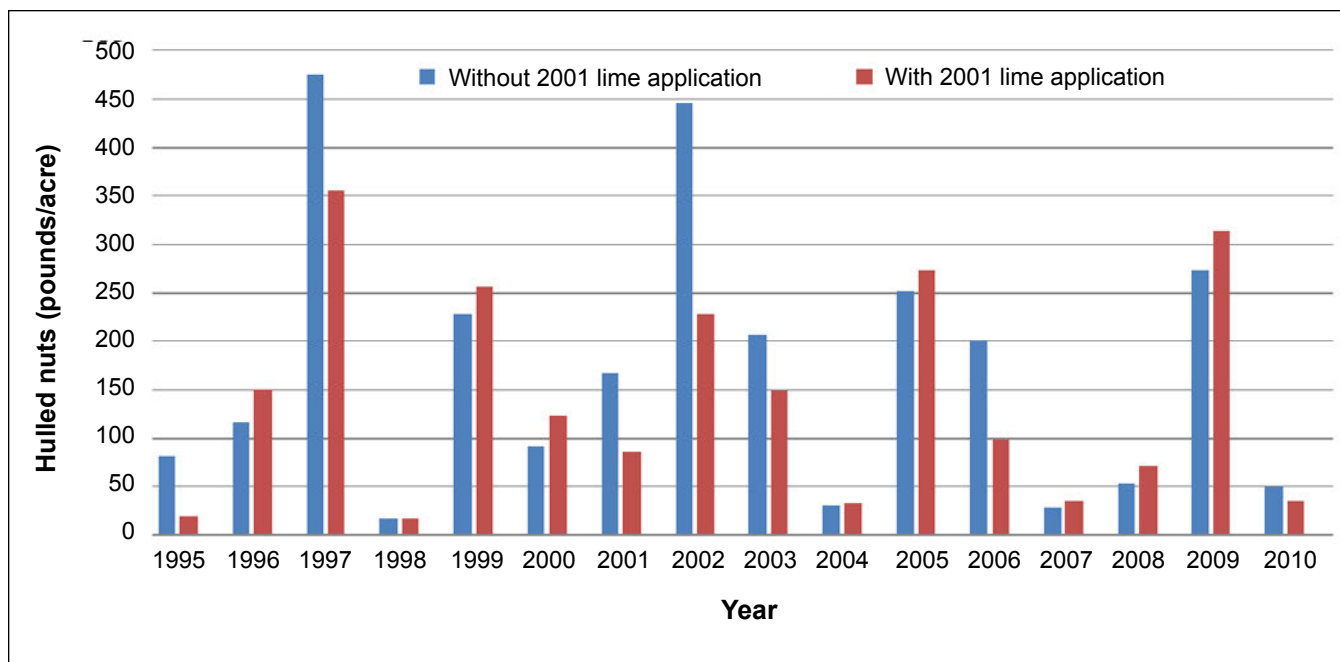


Figure 4.—Average annual nut production on 9 stands before and after application of lime in 2001 compared to the 12 stands that were not limed in 2001.

stands to be slightly more productive than the other stands (Fig. 5). Ponder and Schlesinger (1986) found that the response of walnut to a single application of nitrogen fertilizers usually disappears after 2 to 3 years. There is a trend for increased nut production in 2002 and 2003 for stands receiving the spring/fall

split application of nitrogen (Fig. 5). Of the five stands that received the split N application, only stands 19, 20, and 23 were in the top consistent producers over the post-treatment period; however, all five stands were among the top producing stands in 2002, the first year after treatment.

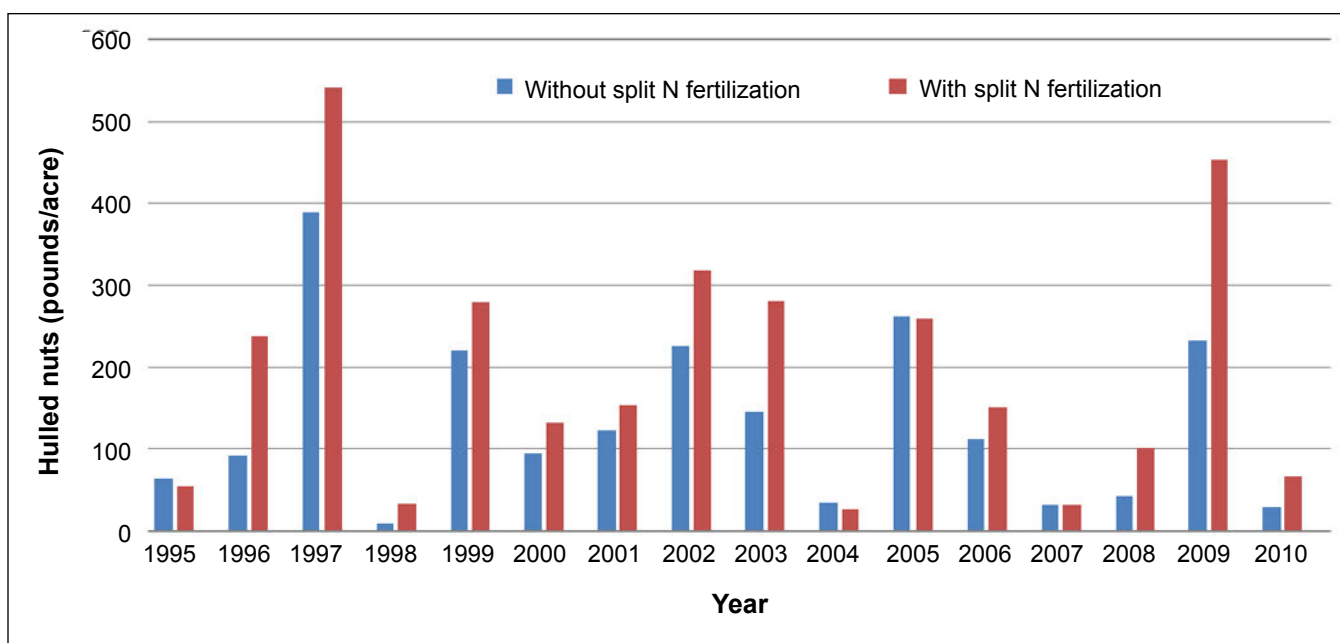


Figure 5.—Average annual nut production on 5 stands before and after a 50:50 spring:fall split application of 120 pounds of nitrogen in 2001 compared to 16 stands that received only 60 pounds of nitrogen during August 2001.

About 510 tons of husk and mill wastes were applied to 14 stands with rates per acre ranging from 0.2 to 11 tons per acre. Statistically, application of husk and mill waste did not result in increased nut production after treatment (2002-2006) compared to pretreatment nut production (Fig. 6). This finding may be partly because application rates varied considerably among stands with less than 1 ton per acre in stands 4, 10, and 23 to more than 7 tons per acre in stands 1, 16A, 17, and 24.

DISCUSSION

There is little evidence that a thinning and one-time application of several fertilizer treatments have substantially increased nut production on walnut from nursery-run planting stock. Ponder and Jones (2001) found repeated applications of NPK were needed to interrupt the alternate bearing pattern in young black walnut stands. Because tree diameters are not measured periodically across the farm, we do not know if tree growth has increased in response to any of the treatments.

Recommendations exist for proper spacing of walnut trees for nut production and timing of thinning for orchards; however, recommendations are less clear on how to apply in an agroforestry situation when trees are planted in widely spaced rows and narrow spacings within rows. Reid et al. (2009) suggested that, when tree crowns begin to shade each other, nut production will begin to decrease and planting needs thinning. Walnut orchards with trees grafted to nut producing cultivars should be established at a 30 by 30 foot spacing followed by careful selection of trees to be removed to reach a desired final spacing of approximately 60 by 60 feet. In 2001, diameter at breast height averaged between 10 and 12 inches for stands 11, 17, 22, and 23 (unpublished data from other studies). With trees this size and a desired crown competition factor (CCF) of 100, these stands would not need thinning unless they had more than 70 to 90 trees per acre. With initial spacing of trees in rows 40 feet apart and within-row spacing of 6 feet (180 trees per acre), 12 feet (90 trees per acre), and 20 feet (56 trees per acre) that were used on the Sho-Neff

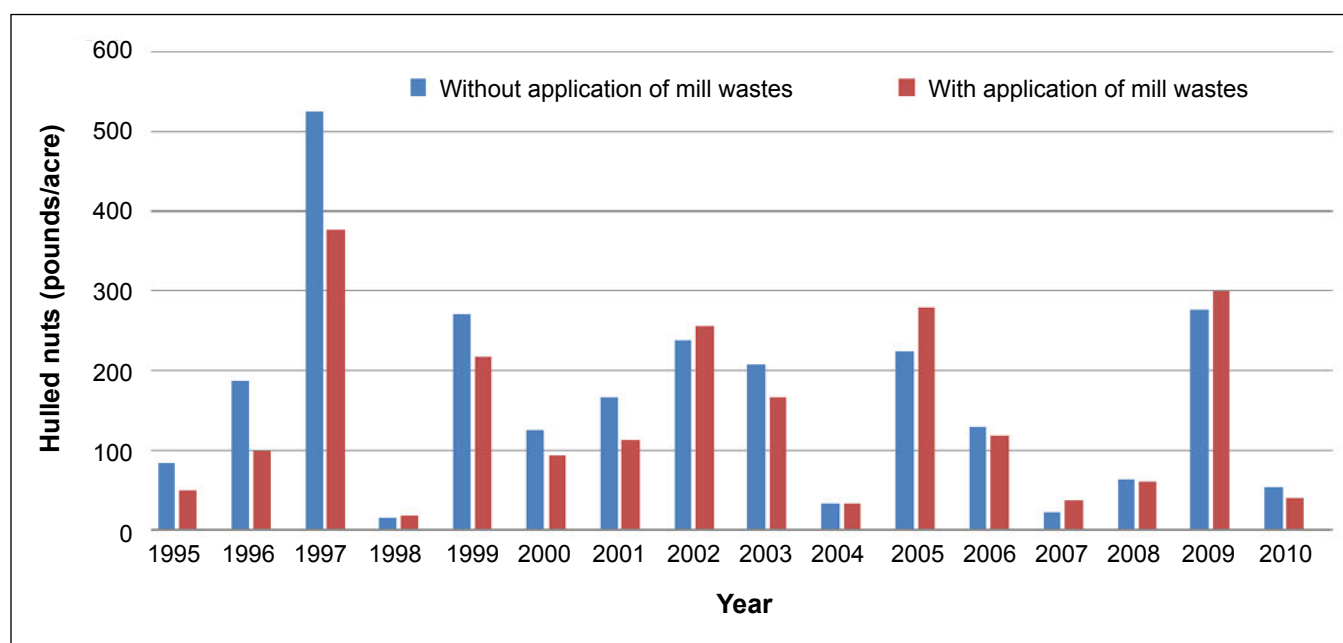


Figure 6.—Average annual nut production in 14 stands before and after application of husk and mill wastes during the 2001 growing season compared to average nut production in 7 stands where husk and mill wastes were not applied.

farm and a thinning in 2001 to remove one-third of the trees, tree-to-tree competition is unlikely to be the major cause of low nut yields.

Although cultural treatments, especially fertilization, have been shown to increase stem diameter growth and nut production (Jones et al. 1995; Ponder 1976, 1998), Garrett et al. (1991) reported that genetic selectivity among wild trees for nut production could also increase production. Nut production over a 7-year period for wild trees that were described as average for nut production was a little less than 3 pounds per tree per year compared to 26 pounds per year for trees selected for their favorable nut-bearing characteristics. Variability in nut production among wild trees was further documented by Jones et al. (1995). Out of a population of 934 trees from nursery-run planting stock, 41 trees had no nuts through age 15, and almost 80 percent of the trees produced fewer than 100 nuts per tree from age 7 through 15. Only three trees averaged more than 300 nuts annually, and the most prolific tree produced an average of 345 nuts per year.

There are wild black walnut plantations that produce abundant nuts. The black walnut trees that were planted on the Al Goetsch tree farm (A. Goetsch, pers. commun.) in Wisconsin are very productive and dependable for high nut yields. However, the trees are more than 70 years of age, the crowns are large, and the trees are widely spaced. Some of the trees are better and more dependable for nut production than others. They also are veneer quality trees. This plantation of wild black walnut trees demonstrates quite clearly that a plantation can be managed for tree quality as well as nut production, but perhaps significant nut production does not begin until the trees are more mature than those on the Sho-Neff farm.

Another reason for the poor response in nut production to treatments was likely due to the continued harvesting of hay. For some years, hay was cut more than once. Grasses produced for hay remove moisture

and nutrients during their growth and the harvesting of hay removes nutrients from the site. On good walnut sites, competition from grasses and other weeds reduced growth significantly (Van Sambeek 1989, Van Sambeek and Garrett 2004, von Althen 1977). On marginal walnut sites, the reduction in tree growth due to grass cover may be even more severe (Ponder 1991). Holt and Voeller (1975) reported that plots where tall fescue sod had been eliminated averaged 28.7 pounds of nuts compared to only 13.6 pounds of nuts in tall fescue sod over 5 years. Grasses such as tall fescue have long fibrous roots that can extract water and available soil nitrate nitrogen from deep soil volumes, resulting in a drier and more nutrient-poor profile (Burch and Johns 1978, Van Sambeek et al. 1989).

It has been demonstrated in fertilization of pecan orchards that a potentially undesirable side effect of high nitrate concentration within the tree is that it acts as a “quasi-hormone” (Wood and Reilly 2011). High nitrate nitrogen can stimulate vegetative growth processes such as shoot growth at the expense of reproductive processes such as flowering and kernel filling. Thus, if black walnut behaves in a similar manner, high endogenous nitrate caused by the application of nitrate-N sources could reduce flowering, nut yield, and nut quality of trees. This means that excessive tree nitrate concentrations in young trees are more likely to promote vegetative growth than to maximize nutmeat yields. By comparison, pecan trees fertilized with ammonium-N sources tend to have higher carbohydrate and protein concentrations than those fertilized with nitrate-N sources. Although we are not sure how much can be extrapolated from the findings from pecan fertilization research (Wood and Reilly 2011), it is remarkable when we consider that tree carbohydrate reserves play a major role in ensuring return flowering and reduced alternate bearing in pecan. Additional studies are needed on walnut of nut bearing age to determine if the N source also affects their nut quantity and quality.

MANAGEMENT IMPLICATIONS

The treatments of thinning and additions of fertilization and walnut mill and husk wastes were applied to wild plantation walnut trees between 20 and 25 years old to increase soil nutrients, growing space, and presumably nut production. Nut production increased only slightly and this increase was not the same for all stands. This finding suggests that nutrients were not the primary limiting factor for nut production. Tree density was reduced and most likely the availability of light and soil resources was increased, creating conditions that were favorable for growing grasses for hay, which removed nutrients from the site, but did not increase nut production. After treatment, nut production was somewhat higher on trees on the upland fields than on trees on the bottomland fields suggesting that treatments benefited upland trees more than bottomland trees. We attribute the small increase in nut production on the upland to increased available soil moisture. Alternate-year bearing was not eliminated by treatments. The modest gain in nut production suggests that neither soil fertility nor thinning was a major factor limiting nut production for trees in this study. It appears that the wild black walnut tree delays significant nut production until it is able to compete for sun in the forest environment.

It is unfortunate that thinning and fertilization were done simultaneously because it eliminated the opportunity to draw meaningful conclusions about the efficacy of either procedure regarding nut production. Without better prescriptions for increasing nut production of wild black walnut, growers of these trees should not assume that nut production will respond to thinning and fertilization before trees are physiologically mature.

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