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Annual Applications of N, P, and K for Four Years Moderately Increase Nut Production in Black Walnut

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Abstract. **Annual applications of N, P, and K fertilizers were broadcast for 4 years around black walnut trees (*Juglans nigra* L.) in an upland plantation to determine their effect on nut production and foliar nutrient levels. Fertilization significantly ($P = 0.05$) increased nut production, treatments containing P with N and/or K being most effective. Doubling the rate of application did not produce a corresponding yield in nuts. Increases in leaf concentrations of N, P, and K were associated with increasing treatment levels of these elements. Levels of all elements tested, except P, were above deficiency levels. The modest gain in production suggests that soil fertility was not a major factor limiting nut production for trees in this study.**

Many hectares of artificially regenerated black walnut trees are of nut-bearing age and size, but very few of these trees are producing substantial nut crops. Various reasons for low production include poor cultural treatments, environmental factors, and genetics. Also confounding nut production is the irregular bearing pattern that is typical of many fruit and nut trees (Sparks, 1974).

Flower abundance is a critical factor in production, and the initiation of female flower primordia appears to be linked to adequate carbohydrate reserves (Sparks, 1974). Unfortunately, the nut-bearing black walnut tree has to support two major demands on carbohydrate resources simultaneously, viz., female flower initiation and the final stages of fruit maturation (Van Sambeek and Rink, 1981). Producing sufficient leaf area to support the tree's needs during nut maturation and flower initiation is therefore essential. Leaf area may be increased by improving tree vigor, resulting in more branches and shoot growth.

Much attention has been directed to increasing tree growth in black walnut, but little to increasing nut production. The value of the nut crop also can be increased by practices that increase vigor, especially fertilization (Garrett et al., 1991; Garrett and Kurtz, 1983; Jones et al., 1995; Ponder, 1976). Jones et al. (1995) reported that late summer fertilization with equal amounts of N, P, and K was more beneficial for nut production than was spring fertilization. They attributed the better response to late summer fertilization to improved nutrition at a time when fruit production is drawing heavily on carbohydrate reserves, and to reduced nutrient loss to soil leaching. Nutrient guidelines for improving black walnut production are not available. In this paper, we assess the effects of fertilizer combinations on nut production and changes in leaf nutrient levels of artificially regenerated black walnut.

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Methods and Materials

The study site was an upland black walnut planting on the ShoNeff Plantation in southwest Missouri, owned and operated by Hammons Products Co. of Stockton, Mo. Soils in the study site are primarily of the Britwater series, which are deep, nearly level to moderately sloping, and moderately well-drained. These upland soils are Typic Paleudalfs, fine-loamy, mixed, mesic, and were derived primarily from acid sandstone. Soils in the study area had a mean pH of 6.4, cation exchange capacity (CEC) of 11.2, 72 mg·ha^{-1} of available P, and 200 mg·ha^{-1} of available K prior to fertilizer application. These nutrient concentrations are moderately high for this soil.

The trees, developed from seedlings obtained from the Missouri Dept. of Conservation nursery in Licking, were 18 years old, and their trunk diameters at breast height (1.4 m from the ground) ranged from 20.5 to 25.0 cm. They were planted in rows at a 12 × 6-m spacing. Weeds were controlled with glyphosate [*N*-(phosphonomethyl) glycine] and simazine (6-chloro-*N*′,*N*′-diethyl-1,3,5-triazine-2,4-diamine) mixture containing 602 and 481 g·ha^{-1}, respectively, in 235 L of solution per treated hectare, applied annually in 1.5-m-wide bands along both sides of the row, using a tractor-drawn sprayer.

All study trees were numbered and trunk diameter at breast height was recorded. The 12 treatments in the experiment included two fertilizer rates, five fertilizer treatments, and a nonfertilized control for each rate. Each of 12 treatments was applied to one row of six trees annually for 4 years. Treated rows alternated with nontreated rows of trees. Fertilizer treatments included N and K separately and in combination, with and without P at two rates. Fertilizers used were NH_4NO_3 (52.5% N), triple superphosphate (46% P), and KCl (60% K). The amounts of N, P, and K used were based on mass of fertilizer materials and not actual nutrients. Nitrogen and P were applied at rates of 310 and 620 kg·ha^{-1} each, and K was applied at rates of 490 and 980 kg·ha^{-1} annually in the spring for 4 years. Fertilizers were measured and broadcast around trees over an area that approximated the crown area. Nuts were harvested by hand, counted, and bagged according to tree number. Hammons Products Co. ran all nuts through a mechanical huller to remove the husk before open-air storage. Nuts were weighed only in 1995.

Leaf samples were collected from nonfruiting, midcrown branches in three locations around the tree in middle to late July in 1993 and 1996 and analyzed for N, P, and K. Calcium was measured in 1996. Leaflets were removed from the rachis and put into paper bags; damaged leaves were discarded. Samples were a composite from all three locations on a tree. Leaves were dried in a forced-air oven at 70 °C for 48 h and ground in a Wiley mill to pass a 20-mesh screen. All samples were analyzed at the Ohio State Univ. Research Analytical Laboratory at Wooster. Phosphorus, K, and Ca were determined by the inductively coupled plasma method (Perkin-Elmer Corp., 1983) and N was determined by the Dumus method (Leco Corp., 1984).

Because each treatment was applied to only one row of trees, the rates of application were considered as blocks. Average values for the six trees in each treatment were analyzed, giving two replicates (blocks) per treatment. Thus, interactions between rate of application and the other factors tested could not be analyzed. Treatment effects on nut counts were tested using orthogonal comparisons for planned comparisons. Prior to analysis, the data were transformed to equalize variance using $\log_{10}$ transformation. Data were analyzed using analysis of variance and comparisons were made using the least significance differences (LSD) test (SAS Institute, 1987). Pearson correlation coefficient was used to test for associations between nut counts and foliar nutrient levels.

Results and Discussion

Nut production. Nut counts differed significantly ($P = 0.05$) among years and treatments, but their interactions were nonsignificant (Table 1). There were large variations (0 to 1661) in the number of nuts produced per tree per year, which exceeded those reported (0 to 345) by Jones et al. (1995). Orthogonal comparisons designed to examine combinations of treatments on nut counts indicated no significant difference ($P = 0.05$) between the numbers of nuts on control vs. fertilized trees (= block effect) (Table 1). However, similar comparisons indicated significant differences between N vs. no fertilizer, P vs. no P, and N plus P vs. all other treatments. This suggests that the lack of P may limit nut production.

When treatments were first applied in 1993, flower primordia for the 1993 nut crop had already developed. Therefore, this first application probably had little effect on the 1993 nut crop. Annual nut production over the 4-year period was irregular (Fig. 1). Although the nut crop for 1995 was larger than that for 1993, it was much less than the 1994 or 1996 crops. Irregular bearing occurs in many fruit trees having late-season fruit maturation, and may be related to the carbohydrate concentration in the plant (Sparks, 1974). Cultural practices that increase the leaf area and vigor may reduce irregular bearing (Sparks, 1974).

The cumulative mean number of nuts per tree was highest in treatments containing N and P with or without K followed by P and K (Table 2). Phosphorus was not applied alone. Ponder (1976) reported an increase in nut production associated with applications of P-containing fertilizers for naturally regenerated trees that were thinned. The cumulative number of trees producing nuts was not affected by treatment.

Nut mass was more than doubled in trees receiving the single rate treatments and more than tripled in trees receiving the double rate relative to the mass of control trees (Table 3). The value of the nut crop was also increased (Table 3). We did not evaluate yield and quality of the kernels. Fertilization of English walnuts (*Juglans regia* L.) significantly increased kernel mass and percentage of filled kernels, with no change in nut size (Serr, 1960).

Annual fertilization costs ($2618/ha for N, $1314/ha for P, and $854/ha for K, all at the single rate) were considered excessive relative to the increased value of the nut crop (Table 3). The amount of fertilizers used was substantially greater than that used by Jones et al. (1995), who increased nut production significantly by applying 0.18 kg of 13N–13P–13K per centimeter of trunk diameter in late summer. However, they concluded that the rate was marginal and did not stimulate nut production when applied in the spring.

Nutrition. Although nutrient levels were generally higher in the 1996 leaf samples, the increase over 1993 was nonsignificant. However, comparisons of specific treatment combinations showed that foliar concentrations of both N and P for 1996 were significantly ($P = 0.05$) affected by fertilization, but concentrations of K and Ca were not. All treatments containing N, except the NPK treatment, increased foliar N concentrations. Treatment means for N concentrations ranked by a LSD test were N>NP>NPK>PK>control>K. Mean foliar P was highest in leaves from trees that were not treated with N. Treatment means for foliar P ranked in the order K>PK>control>N>NP>NPK. The higher concentrations of leaf P were probably not the result of more P being taken up by trees in treatments not containing N. On soils to which either banded or broadcast P is added, N additions generally increase total P uptake by plants (Grunes, 1959). Apparently, the relatively lower P concentrations in leaves in treatments with N indicate that adding N increases the use of P in nut production. Nut production tended to be higher on trees fertilized with N and P than with N or K alone. Furthermore, the low mobility of P suggests that very little, if any, of the P broadcast in this study moved into the rooting zone. Phosphorus had moved only 37.5 cm into the soil after 115 years of annual broadcast applications of 33 kg·ha^{-1} of P as superphosphate (Russell, 1973).

Very little information is available relating black walnut nutrient levels to nut production. Much more information is available about the

Table 1. Analysis of variance table for test of fertilizer effects on differences between number of black walnuts for year, treatment, rate, and their interactions and treatment comparisons.

Source	df	SS	MS	F	$P > F$
Rate (= block)	1	16281	16281	1.59	0.2206
Year	3	765183	255061	24.84	0.0001
Treatment (trt)	5	146136	29227	2.85	0.0383
Year × trt	15	201380	13425	2.54	0.1896
Treatment comparisons	5				
No fertilizer vs. any	(1)	7326	7326	0.71	0.4070
N vs. no fertilizer	(1)	53399	53399	5.20	0.0322
P vs. no P	(1)	107992	107992	10.52	0.0106
K vs. no K	(1)	15376	15376	1.50	0.2334
N and P vs. others	(1)	50866	50866	9.64	0.0361

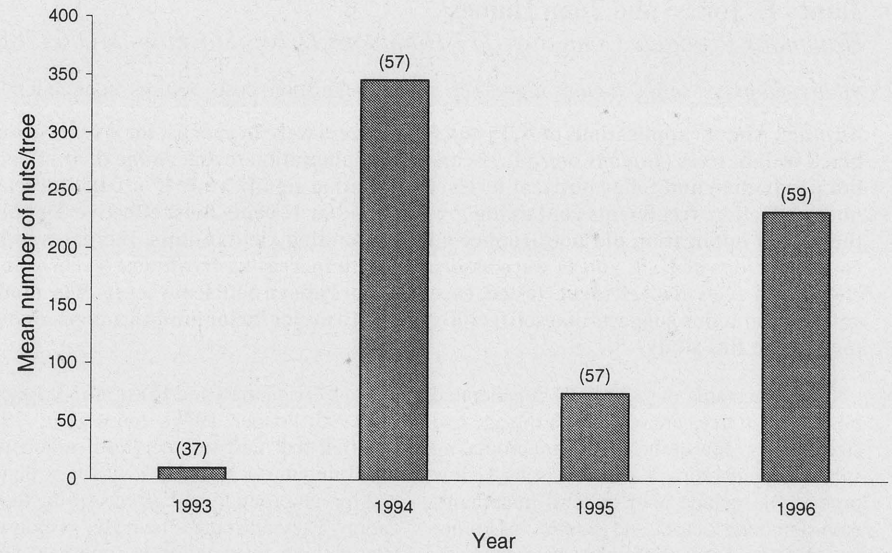

Fig. 1. Mean number of nuts/tree in a fertilized upland black walnut planting over 4 years. Numbers in parentheses indicate the number of observations (trees with nuts out of 72) used to generate each mean.

Table 2. Effects of fertilizer and rate of application on mean cumulative number of nuts produced per black walnut tree in an upland 1975 planting over 4 years. Fertilizers applied annually each spring.

N–P–K (kg·ha^{-1})			Single application		Double application[z]	
			No. nuts	SD	No. nuts	SD
0	0	0	91 (19)[y]	161	106 (19)	200
310	0	0	97 (20)	117	99 (19)	163
310	310	0	203 (21)	254	220 (20)	135
310	310	490	213 (18)	313	212 (20)	378
0	310	490	194 (17)	318	146 (17)	269
0	0	490	114 (21)	165	50 (18)	86

[z]Total fertilizer applied = 2× that for single rate.
[y]Cumulative number of trees out of a total of 24 that produced nuts during the 4-year study period.

Table 3. Mean yield and value in 1995 for black walnut trees fertilized for 3 years.

Fertilizer	Total cost per tree ($ U.S.)	Yield (kg/tree)	Value ($ U.S.)[z] per tree	Value ($ U.S.)[z] per ha (136 trees)
None	0	2.0	0.54	73.44
Single rate	35.19	5.1	1.38	187.68
Double rate	70.38	7.2	1.94	263.84

[z]At $0.27/kg.

effect of nutrient levels on walnut growth. Therefore, it seems reasonable to assume that nut-bearing walnut trees that have foliar N, P, K, and Ca concentrations in the same range as those appropriate for vigorous growth should also be capable of producing "good" nut crops.

The average concentrations of N, P, K, and Ca in black walnut leaves from a mixed natural stand were 2.18%, 0.32%, 2.45%, and 2.68%, respectively, in August (McHargue and Ray, 1932). Their data showed that while P and K concentrations declined from May to August, the decline was more rapid for N, which decreased from 4.57% to 2.18%. Calcium concentrations increased over the same period from 1.06% to 2.68%. According to Phares and Finn (1971), black walnut may or may not respond to fertilization when N, P, K, and Ca concentrations in leaves are 2.00% to 2.60%, 0.10% to 0.25%, 0.75% to 1.30%, and 0.50% to 1.10%, respectively. Lower concentrations are considered deficient and such trees should respond to fertilization. The mean concentrations of N, P, K, for leaves sampled in 1996, were 2.74%, 0.19%, and 1.86%, respectively, compared with 2.71%, 0.17%, and 1.64%, respectively, in leaves sampled in 1993. These values strongly suggest that, except for P, pretreatment levels of these nutrients were probably adequate for nut production. The mean Ca concentration was 2.30% in leaves sampled in 1996. It was not measured in 1993. Calcium concentration was significantly correlated ($r^2 = 0.38$; $P = 0.05$) with nut production. The immobility of Ca in the phloem and its consequent failure to be retranslocated from old to new leaves causes its concentration to increase (Loneragan and Snowball, 1969), while concentrations of mobile nutrients, such as N and K, decrease during the season (Ponder et al., 1979). Thus, any reduction in vegetative growth that may be associated with nut production could cause Ca concentrations to increase in the older leaves. Foliar nutrient levels that are associated with acceptable walnut growth can also be considered as sufficient for nut production. However, interpreting nutrient leaf data for only 2 years can be misleading. Many more years of testing must be done before firm fertilization recommendations can be made.

Black walnut nut production in our study was higher following broadcast applications of P in combination with N and/or K. The study did not determine if P alone would have given the same response. Alternate bearing was not eliminated by fertilizer treatments, but maintaining adequate nutrient levels in black walnut trees of nut-bearing age over the growing season can increase nut production.

Literature Cited

Garrett, H.E., J.E. Jones, J.K. Hanes, and J.P. Slusher. 1991. Black walnut nut production under alley cropping management: An old but new cash crop for the farm community. Proc. 2nd N. Amer. Agroforestry Conf. H.E. Garrett (ed.). Springfield, Mo., 18–21 Aug. 1991.

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

Grunes, D.L. 1959. Effect of nitrogen on the availability of soil and fertilizer phosphorus to plants. Adv. Agron. 11:369–396.

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

Leco Corp. 1984. Instructional manual. Leco Corp., St. Joseph, Mich.

Loneragan, J.F. and K. Snowball. 1969. Calcium requirements of plants. Austral. J. Res. 20:465–478.

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

Perkin-Elmer Corp. 1993. Inductively coupled plasma manual. Perkin-Elmer Corp., Norwalk, Conn.

Phares, R.E. and R.F. Finn. 1971. Using foliage analysis to help diagnose nutrient deficiencies in black walnut. Northern Nut Growers Assn. Annu. Rpt. 62:98–104.

Ponder, F., Jr. 1976. Fertilization and release increases nut but not wood production of pole-sized black walnut. Northern Nut Growers Assn. Annu. Rpt. 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. Plant Anal. 10:1513–1521.

Russell, E.W. 1973. Soil conditions and plant growth. 10th ed. Sheck Wah Tong Printing Press, Hong Kong.

SAS Institute. 1987. SAS/STAT guide for personal computers. ver. 6. SAS Inst., Cary, N.C.

Serr, E.F. 1960. Response of Persian walnut to superphosphate. Proc. Amer. Soc. Hort. Sci. 77:301–307.

Sparks, D. 1974. The alternate fruit bearing problem in pecans. Northern Nut Growers Assn. Annu. Rpt. 65:145–158.

Van Sambeek, J.W. and G. Rink. 1981. Physiology and silviculture of black walnut for combined timber and nut production. Northern Nut Growers Assn. Annu. Rpt. 72:100–107.