Site Relationships and Black Walnut Height Growth in Natural Stands in Eastern Kansas

Wayne A. Geyer and Felix Ponder, Jr.[1]

ABSTRACT—Prediction of forestland productivity is needed for proper species selection in tree planting. By relating site quality to site and soil characteristics, potential productivity can be estimated for non-forested areas. Our study measured the growth potential of black walnut in natural stands in southeastern Kansas. We looked at over 200 stands on unglaciated soils. Numerous environmental factors were evaluated within the following broad categories: site, soil chemical, and soil physical. These environmental factors were related to tree height at the age of 50 years. Simple correlation and multiple regression analyses were run against site index using over 60 variables of soil and topographic characteristics. Depth to a restrictive layer explained 74% of the variation in height.

The natural range of black walnut (*Juglans nigra* L.) extends westward into central Kansas (Williams 1990). Walnut is found as a major component of the prairie-forest fringe environment in eastern Kansas. Although nearly pure stands of black walnut are uncommon, it is found on a wide variety of ecological sites. Most often, black walnut occurs as small patches along the river valleys, side drainages and adjacent slopes, and is often bordered by abandoned cropland and abused pasture-land (Grey and Naughton 1971).

Generally black walnut is found on deep, moist, well-drained areas having good soil structure (Auten 1945, Carmean 1970) and near neutral in reaction (Spurway 1941, Wilde 1934). Soil reaction and nutrient levels were related to walnut growth in 15-year-old walnut plantations in southeastern Iowa (Thompson and McComb 1962). Prediction equations, using important soil and topographic variables, have been generated in an earlier study by Geyer and others (1980) for northeastern Kansas.

Our study attempts to relate tree growth differences as indicated by site index at 50 years to many physical and chemical site factors. Generally, factors relating to moisture availability are of utmost importance to tree growth.

METHODS

Description of the Study Area

The study area is located within the Central Lowlands physiographic province (Keys and others 1995). Elevations range from 800 to 1200 feet. The surface soils are mostly of silt loam to clay loam texture, often with limestone and shale outcroppings on the slopes. Most are of Mollisol origin (soils that developed under prairie vegetation). The climate is typical continental with most of the precipitation in the warm season. The study range covered over 135 miles north and south and 115 miles east to west with moisture patterns of 28 inches annual precipitation in the northeast to 45 inches in the southeast portions of the study area (Fig. 1).

Field Plots

Our investigation evaluated over 210 plots in the unglaciated area of southeastern Kansas on all topographic positions (upland, bottomland, lower slopes, and intermittent streams) and generally well distributed on all four-direction quadrants. About two-thirds of the study plots were given detailed

[1]Professor of Forestry (WAG), Division of Forestry, Throckmorton Hall, Kansas State University, Manhattan KS and Research Soil Scientist (FPJr), North Central Research Station, USDA Forest Service, 208 Foster Hall, Lincoln University, Jefferson City, MO 66506. WAG is the corresponding author: to contact, call 785-532-1409 or e-mail at wgeyer@oznet.ksu.edu.

Citation for proceedings: Michler, C.H.; Pijut, P.M.; Van Sambeek, J.W.; Coggeshall, M.V.; Seifert, J.; Woeste, K.; Overton, R.; Ponder, F., Jr., eds. 2004. Black walnut in a new century, proceedings of the 6th Walnut Council research symposium; 2004 July 25-28; Lafayette, IN. Gen. Tech. Rep. NC-243. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 188 p.

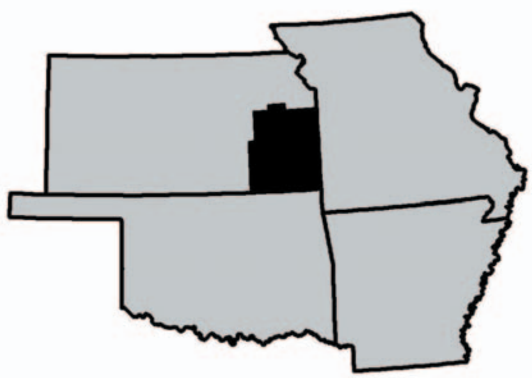

Figure 1.—Study area for location of black walnut field plots.

analysis. The remaining plots were discarded because of discrepancies in tree numbers, tree quality, and missing data. All plots were located in natural hardwood timber stands containing significant amounts of black walnut.

Trees selected for analysis were in dominant and/or codominant crown classes and had no visible signs of stagnation or suppression. We measured two to four walnut trees in each plot. Total height of each tree was measured with a Blume-Leiss altimeter. Tree age was determined from core samples of wood taken at about 4 inches above the ground. Using Kellogg's site index curves for walnut plantations (Kellogg 1939) and plot averages of height and age, we evaluated site index. Site index is the average height of dominant and codominant trees in a stand at age 50 years. Taller trees at a given age indicate a site of higher productivity.

Site Variables

We classified each site by topographic characteristics and each soil profile by soil parent material, either alluvial (bottomland) or residual (upland), and assigned values of +1 or –1, respectively. Landform was classified as bottomland, intermittent stream, lower one-third slope or upland, and assigned values of 1, 2, 3, or 4. Azimuth and slope were determined with a compass pointed down slope through plot center and an altimeter, respectively. Assuming the northeast aspect as the most favorable for tree growth and southwest as the least favorable, we tested two transformations of aspect. First, the cosine (azimuth – 45 deg.) +1 as described by Beers and others (1967) and second, the corrected azimuth from the southwest as described by Munn (1974) along with true azimuth to see if they would correlate with walnut growth. Slope steepness was expressed as slope percentage, less than 10%, less than 5% or equal to or exceeding 10%.

Other variables tested were depth to a restrictive layer (defined as textural B horizon—a massive rock layer, gravel layers of at least 75% rock, a water table, mottling, or 60 inches, whichever occurred at the least depth), and effective depth to a restriction (defined as rock percentage in inches removed from depth to restriction). Also total soil depth, effective soil depth (defined as rock percentage in inches removed from total soil depth), (Steinbrenner 1965) and water holding capacity of total soil depth or water-holding capacity to the restrictive layer. Both are sums of available water-holding capacity calculated by textural horizons.

Soil Analysis

Soil pits were located in between the trees and were dug to a maximum of five feet and the morphological characteristics of each soil profile described. One soil sample from each horizon was analyzed in the laboratory for both chemical and physical characteristics. Soil textures were determined by the Bouyoucos method (1951), except sodium hexametaphosphate was used instead of Calgon as a dispersing agent. Chemical tests were run for both the surface and subsurface horizons. Lime (ECC/ac) pounds needed for crop production, pH, Bray 1 phosphorus, potassium, calcium, magnesium, sodium, and organic matter were done by the Kansas State University Soil Testing Laboratory using standard agricultural testing procedures. The relationship between site index and soil factors was evaluated using simple correlations. Correlation coefficients for the 60 independent variables were calculated with the independent variable, site index, to find the best for generating a multiple regression equation using the stepwise backward elimination procedure (Barr and others 1976).

RESULTS AND DISCUSSION

Analyses of the data showed the largest simple correlation of site index was with soil depth to a restrictive layer (r = +0.85). Other highly correlated factors were rooting depths, expressions of water holding capacity, and soil parent material. Three of the four factors (soil depth, rooting depths, and expressions of water holding capacity) are very closely related. Deep soils can hold more water and have more space for root development. Soil moisture is likely the underlying factor associated with the high correlation of soil depth and site index. Even though black walnut is deep rooted, almost 80% of its root system occupies the upper 24 inches of the soil (Pham and others 1978). Water needs for black walnut are greatest during the growing season at a time when soil water content within the rooting zone decreases due to plant uptake and evapotranspiration. Carpenter and Hanover (1974) reported that for black walnut seedling height growth slows after mid June and ceases by late July, suggesting that seasonal height growth is completed early for the species. These authors also suggested that black walnut is typical of those deciduous species with preformed seasonal shoot growth.

Black walnut is believed to function as drought avoidance species as opposed to drought tolerant species (Lucier and Hinckley 1982). As a drought avoidance species, black walnut is able to maintain plant water content near optimum levels during periods of low soil moisture availability and high atmospheric evaporative demands by initiating stomatal closure restricting photosynthesis and depending on the duration of unfavorable conditions, shedding its leaves. An investigation of black walnut site quality in relation to soil characteristics in northeastern Kansas indicated that site index increased as effective soil depth increased (Geyer and others 1980).

Surprisingly, neither aspect ($r = -0.07$, $p = 0.484$), nor the amount of sand in either the surface or subsurface horizons was correlated with site index (surface $r = 0.059$, $p = 0.563$; subsurface $r = 0.05$, $p = 0.618$) or silt + clay (surface $r = -0.07$, $p = 0.487$, subsurface $r = -0.010$, $p = 0.329$). Neither was organic matter (surface $r = 0.47$, $p = 0.001$, subsurface $r = 0.36$, $p = 0.0004$). Aspect and silt plus clay were important to black walnut site quality in northeastern Kansas (Geyer and others 1980). Soil texture was a major determining factor in the growth of planted walnuts in Kentucky (Kalisz and others 1989). The growth rates of young black walnut plantations were significantly greater on suitable compared to questionable soils. In the Kentucky study, approximately 75% of the soils judged to be questionable for walnut management were limited by the presence of clay subsoil, 10% by shallowness to bedrock, 10% by imperfect drainage, and 5% by the presence of a fragipan.

Soil organic matter had a negative relationship when greater than 4.3%, but thickness of the A horizon had an “r” value of 0.66 and $p = 0.0001$ (Table 1). However, it is important to take soil texture into account in this layer because texture affects soil water storage and availability. Another study (Geyer and others 1980) found that coefficients for soil texture in the A horizon decreased with an increase in clay and increased when the silt content of the clay increased.

Soil nutrient concentrations were not positively correlated with site index for any of the tested nutrients (data not presented). However, optimum walnut growth has been suggested to occur when soil pH values range from 6.0 to 8.0 (Spurway 1941). In the present study, calcium and potassium seem to be the overriding factors. We ran a range of surface pH values and found pH was negatively related to site index when greater than 7.4.

Table 1.—Simple correlations with site index (20 thru 80 years age).

Variable	Mean	Range	Simple Correlation (r)
Depth to restrictive layer (DRL)	31.9″	2.0-60.0	+ 0.85
Estimated soil depth to DRL	31.4	3.0-60.0	+ 0.82
Water holding capacity to DRL	6.2	0.4-14.9	+ 0.82
Soil origin (upland/bottomland)	--	+1, -1	+ 0.67
Landform (bottomland/intermittent/			
lower 1/3rd, upland)	--	1,2,3,4	- 0.67
Thickness “A” horizon	20.0	5.3-60.0	+ 0.66
Total soil depth	44.1	6.0-60.0	+ 0.66
Estimated soil depth	41.0	5.3-60.0	+ 0.64
Water holding capacity all horizons	8.1	1.0-14.9	+ 0.63

CONCLUSION

Depth to restrictive layer was a good predictor of height growth for black walnut stands in eastern Kansas. The positive coefficient in the equation for this variable indicates that site index increased as the effective soil depth increased. Many factors used in this study were related to each other and we selected those most apparent and easy to recognize for developing our multiple regression equations. Our best equation, site index = 43.84 + 0.443 depth to restrictive layer + 1.98 soil type, explained 74% of the variation in height. Adding the other soil factors improved predictability by only 5%. Avoiding sites with shallow soils and other properties that reduce water availability and concentrating management on good sites will save resources and increase the growth and value of the trees. Although, data for this study was collected in southeastern Kansas, these results should be useful and applicable for areas in surrounding states.

LITERATURE CITED

Auten, J.T. 1945. Some soil factors associated with site quality for planted black locust and black walnut. Journal of Forestry. 43: 592-598.

Barr, A.J.; Goodnight, J.H.; Sall, J.P.; Helwig, J.T. 1976. A user's guide to SAS. Raleigh, NC: SAS Institute, Inc. 329 p.

Beers, T.W.; Dress, P.E.; Wensel, L.C. 1967. Aspect transformation in site productivity research. Journal of Forestry. 65: 22-24.

Bouyoucos, G.J. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. Agronomy Journal. 43: 432-437.

Carmean, W.H. 1970. Tree height–growth patterns in relation to soil and site. In: Tree. Corvallis, OR: Oregon State University Press: 499-512.

Carpenter, S.B.; Hanover, J.W. 1974. Comparative growth and photosynthesis of black walnut and honey locust seedlings. Forest Science. 20: 317-324.

Geyer, W.A.; Marquard, R.D.; Barber, J.F. 1980. Black walnut site quality in relation to soil and topographic characteristics in northeastern Kansas. Journal of Soil and Water Conservation. 35: 135-137.

Grey, G.W.; Naughton, G. 1971. Ecological observations on the abundance of black walnut in Kansas. Journal of Forestry. 69: 741-743.

Kalisz, P.J.; Stringer, J.W.; Hill, D.B. 1989. Growth of young black walnut plantations in Kentucky. Northern Journal of Applied Forestry. 6: 17-20.

Kellogg, L.F. 1939. Site index curves for plantation black walnut in the Central States Region. Note 35. Columbus, OH: U.S. Department of Agriculture, Forest Service, Central States Forest Experiment Station. 3 p.

Keys, J., Jr.; Carpenter, C.; Hooks, S.; Koenig, F.; McNab, W.H.; Russell, O.; Smith, M.L. 1995. Ecological units of the eastern United States—first approximation (map and booklet of map unit tables). Atlanta, GA: U.S. Department of Agriculture, Forest Service.

Lucier, A.A.; Hinckley, T.M. 1982. Phenology, growth, and water relations of irrigated and non-irrigated black walnut. Forest Ecology and Management. 4: 127-142.

Munn, L.C. 1974. Predicting height growth of yellow-poplar from soils and topography on a Muskinggum-Berks-Neotoma soils complex in southeastern Ohio. Columbus, OH: Ohio State University. 61 p. M.S. thesis.

Pham, C.H.; Yen, C.P.; Cox, G.S.; Garrett, H.E. 1977. Slope position, soil water storage capacity, and black walnut root development. In: Balmer, W.E., ed. Soil moisture-site productivity symposium; Myrtle Beach, SC. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 326-335.

Spurway, G.W. 1941. Soil reaction (pH) preferences for plants. Bull. 306. East Lansing, MI: Michigan Agricultural Experiment Station.

Steinbrenner, E.C. 1965. The influence of individual soil and physiographic factors on the site index of Douglas-fir in western Washington. In: Youngberg, C.T., ed. Forest soils relationships in North America. Corvallis, OR: Oregon State University Press: 261-270.

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

Wilde, S.A. 1934. Soil relation to forestry, and its determination by simple tests. Journal of Forestry. 32: 415.

Williams, R.D. 1990. *Juglans nigra* L. black walnut. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America: 2. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 391-399.