THE POTENTIAL FOR EXTENDING THE NATURAL RANGE OF CHERRYBARK OAK ON APPROPRIATE SITES

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Abstract—Five cherrybark oak (*Quercus pagoda*) plantations outside its native range spanning 10 to 50 years in age were studied to determine survival, growth rates, and projected yields. The plantations were located from southern Indiana to eastern Tennessee on former agricultural fields or cleared areas adjacent to minor drainages. Soils of these plantations were evaluated to determine if they had similar characteristics to common soils within the cherrybark oak range using the Baker and Broadfoot (1979) site evaluation guide. Plantations were well-stocked with present volumes of 8,000 to 14,000 board feet per acre (International ¼ Rule) depending on age. Plantations were free from insects or disease symptoms. Oak bole quality in these pure species plantations was a concern with branch scars still occluding on the upper butt log. Diameter growth rates were about 3 inches per decade. Cherrybark oak plantings appeared promising on sites east of its native range in Tennessee on suitable sites, but less so on sites north of its native range in southern Indiana due to susceptibility of frost cracks.

INTRODUCTION

Cherrybark oak (*Quercus pagoda*) is a cherished and highly valued tree in the red oak family known for its fast growth, straight form, wood quality, and acorn production (Belanger and Krinard 1990). The species occurs in major and minor river bottoms of the Atlantic and Gulf Coastal Plains and the northern Mississippi River Valley to southern Illinois on loamy sites of first bottom ridges and well-drained terraces, primarily alfisol and inceptisol soils (fig. 1) (Broadfoot 1969, 1976). Until the early 1990s, cherrybark oak was considered a variety of southern red oak (*Q. falcata*) instead of a separate species (fig. 1) (Belanger and Krinard 1990). Sites supporting cherrybark oak transition to and overlap southern red oak as sites become more upland and drier. Because cherrybark oak is a preferred timber tree, managers have questioned whether the distribution of the species could be extended on suitable sites outside of its natural range, primarily in minor stream valleys. Minor stream bottoms may be distinguished from major bottoms of the Mississippi River as those floodplains and terraces where soils are of local origin (Hodges 1997).

Unfortunately, little is known about adaptability of cherrybark oak beyond its natural range on suitable sites. Considering that the range of cherrybark oak is rather narrow and discontinuities exist between the Atlantic and Gulf Coastal Plains, influence of geographic and climatic variability on cherrybark oak is unknown. Factors that generally impact geographic variability of a species include size of a species' range, amount of environmental diversity within the species' natural range, and extent of range discontinuities (Wright 1976). Schmidtling (2001) suggested the most important climatic variable related to growth and survival of southern pines (*Pinus* spp.) is annual average minimum temperature. Typically, species can be moved west to east and vice versa with similar moisture and temperature regimes (similar isotherms), but south to north transfer influences rate of growth, date of bud break, length of growing season, and resistance to cold temperatures (Schmidtling 2001, Wright 1976). Sporadic weather events such as ice storms, late season frosts, and sudden fluctuations in temperature can also impact tree health when species are moved from southern to northern latitudes.

This study explored the growth of cherrybark oak plantations beyond the species' natural range. Location and substrates of each planting were carefully considered to align with site-species productivity parameters and common soils for sites within the species' natural range. Site evaluation guidelines for cherrybark oak of Baker and Broadfoot (1979) were used to compare site properties and plantation growth outside the natural range to those expressed within the natural range.

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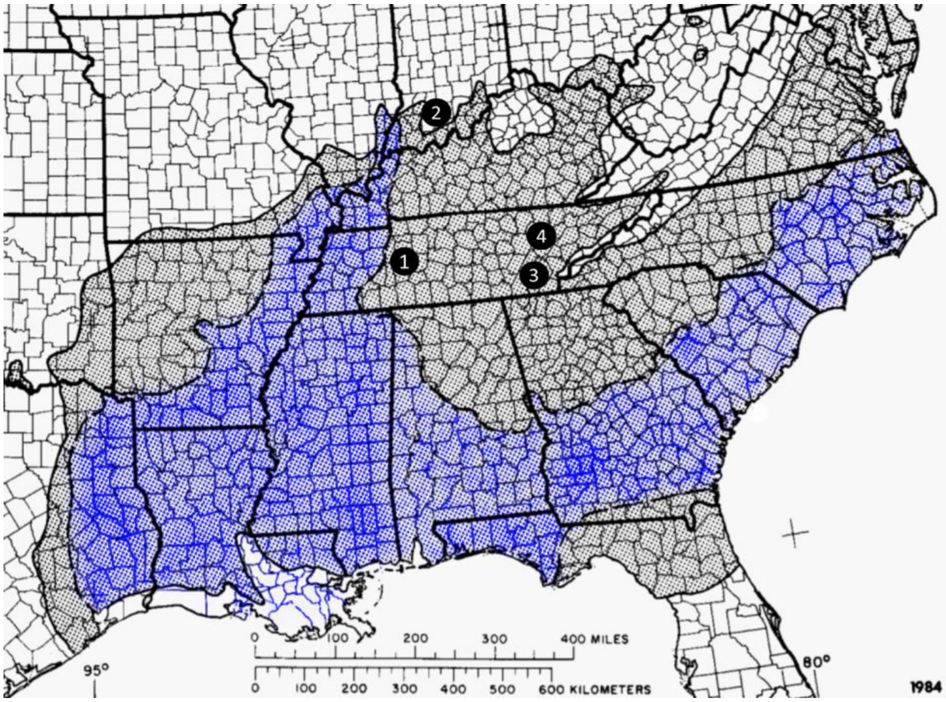

Figure 1—Locations of sampled plantations for the cherrybark oak geographic range study. 1: Natchez Trace State Forest, 2: Pike State Forest, 3: Tennessee State Nursery, and 4: University of Tennessee Cumberland Forest. The blue area represented in the Coastal Plain and the Mississippi Alluvial Plain is the geographic range for cherrybark oak (*Quercus pagoda*) and the more upland gray area is the geographic range for southern red oak (*Quercus. falcata*). Map Source: Belanger and Krinard (1990)

METHODS

Study Sites

Five cherrybark oak plantations were addressed in this study (table 1). All locations were outside the natural cherrybark oak range as designated in Belanger and Krinard (1990). Plantations were located within floodplains of minor streams with entisol or inceptisol soils except for the UT Cumberland Forest that was on the lower slope of an ultisol. Most of the sites were on old fields containing herbaceous vegetation. The exceptions were the PSF sites which had young woody stems and brush that were cut and removed prior to planting. Herbicides were used before planting for site preparation and several times after planting to control competing herbaceous vegetation. Sample plantations infrequently flooded (averaging once every 5 to 10 years) and when they did, duration was just a few days. Area of each plantation was small, ranging from 0.5 to 2.0 acres. Spacing was some variate of 8 feet by 8 feet to 10 feet by 10 feet. Seedling survival from surveys collected a few years after planting exceeded 80 percent for each plantation.

Data Collection

Each plantation was visited in the summer 2018. Diameter at breast height (4.5 feet, d.b.h.) of each tree was measured, total height on a subset of five dominant or codominant trees was tallied, and trees that had succumbed since planting were recorded. Stem analysis was conducted on three to five trees in each plantation to determine height growth rates. Though not presented in this paper, these data were used to corroborate height and diameter measurements. Bole quality as designated by log grade of the butt log for those stems greater than 12 inches d.b.h. was measured in older plantations (Hanks and others 1980). Soils, topography, and drainage were noted on each site and evaluated using soil survey reports and the online web soil survey. From these data, plantation volumes, basal area, and trees per acre were calculated.

Once vegetative and substrate information for each plantation were collected, a site evaluation guide (Baker and Broadfoot 1979) was used to determine if planted locations were suitable for cherrybark oak plantations. This guide uses four soil-site factors for determining site index for various hardwood species. Point values were assigned for various components and added together to establish total site index. A synopsis of factors and components for cherrybark oak are outlined in table 2, but for more detailed information on assessment of each factor/component, reference the Baker and Broadfoot (1979) publication. Point-scored site index values were then compared between plantations with their respective average tree measurements and site conditions to

Table 1—Location and description of the five cherrybark oak plantations

Study site	Location	Managed by	Age	Soil series	Site index for cherrybark oak	Age thinned
			years		*feet at 50 years*[a]	
Natchez Trace State Forest (NTSF) thinned	Henderson County, TN	Tennessee Department of Agriculture, Division of Forestry	50	Iuka (thermic Aquic Udifluvent)	105	Age 24
NTSF unthinned	Henderson County, TN	Tennessee Department of Agriculture, Division of Forestry	49	Bibb (thermic Typic Fluvaquent)	95	Not thinned
East Tennessee (TN) State Nursery	Polk County, TN	Tennessee Department of Agriculture, Division of Forestry	20	Toccoa (thermic Typic Udifluvent)	95	Not thinned
Pike State Forest (PSF) (2 locations 1.5 miles apart)	Pike County, IN	Indiana Department of Natural Resources, Division of Forestry	38	Steff (mesic Fluvaquentic Dystrochrepts)	97	Age 38
University of Tennessee (UT) Cumberland Forest	Morgan County, TN	University of Tennessee, Forest Resources Research and Education Center	10	Lonewood (mesic Typic Hapludults)	87	Not thinned

[a]Clatterbuck (1987)

provide an informed assessment of appropriateness of these sites to extend the natural range of cherrybark oak. Site index for four of the five sampled cherrybark oak plantations was also determined with total height-age relationships of dominant and co-dominant trees using site index curves formulated in minor bottoms of Mississippi (Clatterbuck 1987). The fifth plantation at UT Cumberland Forest was omitted because of its young age (10 years).

RESULTS

Data collected from each cherrybark oak plantation suggested that within their particular age and development timeline, growth trajectories and tree size statistics were remarkably similar (table 3). The NTSF plantation thinned at 24 years had greater diameter and volume, but the plantation that was not thinned had greater basal area and trees per acre. Grade of butt logs (first 16 feet) was greater in thinned plantations averaging a log grade of two due to greater diameters, while butt logs in the unthinned plantations averaged a grade of three because of smaller diameters and exposed branch scars. Both plantations had more numerous surface defects on logs in the upper 8 feet than the lower 8 feet.

The cherrybark oak plantation at the TN State Nursery exhibited phenomenal growth and merchantable volumes after 20 years. Diameter and height growth rate averaged 4 inches and 20 feet per decade, respectively (table 3). These growth rates are expected to diminish somewhat as growing space becomes more limited and trees are increasingly affected by competition from adjacent trees. A thinning to maintain growth rates should take place within the next 5 years.

The PSF cherrybark oak plantations were thinned in the winter of 2017-2018 and the remaining trees measured during the summer of 2018. Table 3 depicts the information after thinning. Growth and volume accumulations were excellent after 38 years with diameter growth rates exceeding 3 inches per decade. Substantial frost cracks were apparent on 32 percent of dominant or codominant trees in one of the two

Table 2—Synopsis of the soil-site properties expressed by the site evaluation guide for cherrybark oak (Baker and Broadfoot 1979)

Factor	Description	
Factor 1	Physical condition (maximum of 31 points; minimum of 19 points)	
	Soil-site properties:	Soil depth and presence of artificial or inherent pan
		Soil texture in the rooting zone
		Soil compaction in the upper one foot of soil
		Soil structure in the rooting zone
		Past use and present cover
Factor 2	Moisture availability during the growing season (maximum of 38 points; minimum of 21 points)	
	Soil-site properties:	Water table depth
		Artificial or inherent pans
		Topographic position
		Microsite
		Soil structure in rooting zone
		Soil texture in rooting zone
		Flooding
		Past use and present cover
Factor 3	Nutrient availability (maximum of 25 points; minimum of 14 points)	
	Soil-site properties:	Geologic source
		Past use and present cover
		Organic matter (A-horizon)
		Depth of topsoil (A-horizon)
		Soil age
		pH in the rooting zone
Factor 4	Aeration (maximum of 31 points; minimum of 16 points)	
	Soil-site properties:	Soil structure in the rooting zone
		Swampiness
		Mottling
		Soil color in rooting zone

The maximum number of points (site index in feet, base age of 50 years) is 125, while the minimum number of points is 70.

Table 3—Summary stand statistics (means) for each sampled plantation for the cherrybark oak geographic range study

Plantation	Age	d.b.h.	Total height	Trees per acre	Basal area	Volume per acre[a]
	years	*inches*	*feet*	*number*	*square feet per acre*	*board feet*
NTSF thinned	50	13	104	145	125	13,500
NTSF unthinned	49	10	98	196	137	10,800
TN State Nursery	20	8	62	248	98	8,600
PSF	38	12	84	114	92	10,200
UT Cumberland Forest[b]	10	3	29	---	---	---

d.b.h. = diameter breast height at 4.5 feet, NTSF = Natchez Trace State Forest, TN = Tennessee, UT = University of Tennessee, PSF = Pike State Forest.

[a] International ¼ log rule.

[b] Mixed species plantation.

plantations (fig. 2). Based on stem analysis, frost cracks occurred sometime during 2006 to 2008 when the trees were 26 to 28 years old.

The UT Cumberland Forest plantation is a mixed species planting research study (Clatterbuck 2016, Schubert and others 2020) with a focus on growth and development of cherrybark oak, presently 10 years old. Although overall (stand) plantation data for the mixed species planting were not directly comparable to the other four pure species plantations measured in this study, diameter and height growth rates of cherrybark oak averaged 3 inches per decade and 3 feet per year, respectively (table 3).

All plantations appeared free from insects and disease. Each plantation was well-stocked to overstocked (basal area ranged from 90 to 140 square feet per acre) with present volume ranging 8,000 to 14,000 board feet per acre (International ¼ Rule). Except for frost cracks encountered at PSF and bole surface defects when assessing log grade, no other tree damage was observed.

The Baker and Broadfoot (1979) site evaluation guide for cherrybark oak was used as another approach to estimate site index. Based on four major soil factors expressed in the guide, a site index range was formulated for each plantation. Site index ranges for each cherrybark oak plantation averaged 95 to 100 feet after 50 years following this guide (table 4). Using Clatterbuck (1987), site index for cherrybark oak was also found to be 95 to 105 feet at 50 years for all plantations, suggesting site productivity was comparable across plantations (fig. 3).

DISCUSSION

Land managers and organizations that planned and planted the sampled cherrybark oak plantations years ago were successful in locating appropriate sites for growth of the species outside its natural range. By selecting sites similar to those found in its natural range, growth trajectories (table 3) and site productivities (fig. 3 and table 4) were similar. Both direct measurement of tree growth using site index curves and use of the Baker and Broadfoot (1979) site evaluation guide yielded similar site productivities. Entisol and inceptisol soils in sampled plantations were slightly less productive (less than 10 to 15 feet in site index) than their counterparts within the cherrybark oak natural range. The difference is probably attributable to soils not being as deep and well-drained as those in Coastal Plain areas. However, the ultisol soil at UT Cumberland Forest was just as productive for cherrybark oak as soils at other sites, but it was also the youngest plantation sampled (10 years). Additional time will be necessary to determine whether early growth rates correspond with growth at later stages or times.

Figure 2—Frost crack (cross section and vertical surface) of a 38-year-old sample tree at Pike State Forest, Indiana. Photo Credit: Wayne K. Clatterbuck (author)

Table 4—Baker and Broadfoot (1979) site index estimations for sampled plantations based on soil-site factors for the cherrybark oak geographic range study

Plantation	Site index
	feet at 50 years
NTSF thinned	100-110
NTSF unthinned	95-100
TN State Nursery	95-105
PSF	95-100
UT Cumberland Forest	85-90

NTSF = Natchez Trace State Forest, TN = Tennessee, PSF = Pike State Forest, UT = University of Tennessee.

Diameter and height growth were comparable at the different chronological times among the five plantations (table 3). The NTSF plantation was thinned (26 years ago) allowing an assessment of the response to the thinning. Both PSF plantations were thinned during the growing season prior to data collection and the future response to thinning is not known. The goal of thinning was to reduce stocking by removing unacceptable growing stock trees. Except for the PSF plantations, all other sampled locations were approaching or were overstocked. Without density control, diameter growth will be reduced. Estimated volume per acre for each plantation corresponds with number of trees, diameter, and basal area (table 2).

The planted, pure stands of cherrybark oak had little, if any crown stratification. Most trees were growing at the same rate and retained lower branches until sunlight became limited at which point branches died and were shed. The branch scars were occluded very slowly because diameter growth was protracted in the excessively stocked stands with little room for additional crown expansion and growth. While the first 6 to 8 feet of most butt logs were relatively clear with few surface blemishes, the upper 8 feet of logs still had defects yielding a log grade of two as the best grade. Although thinning would increase diameter growth rates and occlude branch scars more quickly, most stands had not been thinned, leaving tall, lanky trees of small diameters.

Crowns of mixed species stands often stratify because different species have different growth rates resulting in multi-canopy stands. These stratified stands with differential growth rates often promote better bole grade with slower-growing trees shaping branch-free oak boles. Once oak crowns emerge and ascend above neighboring trees, larger crowns are produced with greater diameter growth rates to occlude the branch scars faster (Clatterbuck and Hodges 1988, Lockhart

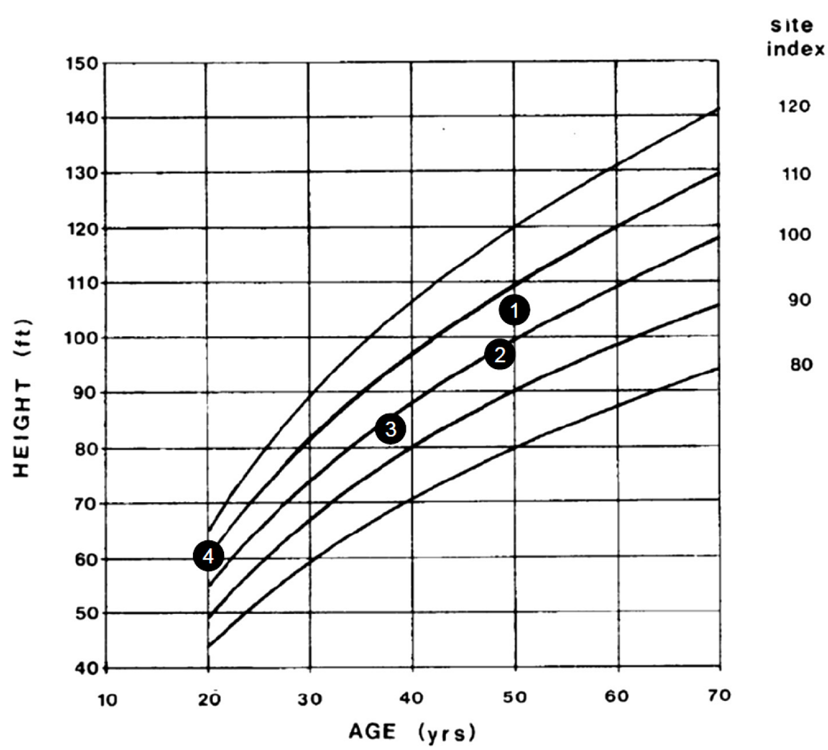

Figure 3—Site index curves for cherrybark oak on minor stream bottoms with site index estimations from Baker and Broadfoot (1979) of the sampled plantations in the cherrybark oak geographic range study (1: Natchez Trace State Forest - thinned, 2: Natchez Trace State Forest – unthinned, 3: Pike State Forest, and 4: Tennessee State Nursery. Site Index Curve Source: Clatterbuck (1987)

and others 2006). Because trees in a monoculture usually grow at the same rate, the opportunity for better log grades is diminishing. Thinning at the appropriate time will increase diameter growth rates and could improve log grade, but branch pruning and occlusion of large-diameter branch scars often wanes because branches are retained longer when more growing space is available. Mixed species plantings should be established to encourage crown stratification for better grade of oaks.

Based on similar growth trends of the five cherrybark oak plantations investigated in this study, the range of cherrybark oak may be extended from west to east on appropriate sites, even though site productivities may be slightly less than those in the natural range. Shifting of range northward should be carefully considered due to cooler and shorter growing seasons. Frost cracks were encountered on some trees at the southern Indiana site. Tree growth was not hampered on the northern site, but log grade was reduced permanently with frost cracks. Future northward expansion studies could be useful to assess extent and severity of frost cracking along a cooler temperature gradient, especially with the advancing climate variability.

CONCLUSIONS

West to east expansion of the natural cherrybark oak range appears feasible on appropriate sites, at least in Tennessee. South to north expansion is problematic with cooler temperatures during the early growing season and possibilities of freezing temperatures having detrimental effects on the tree, such as frost cracks. However, tree and plantation growth were not adversely affected at the location in southern Indiana. For plantings to be successful, suitable sites for cherrybark oak should be determined through objective site evaluation and soils information. Although site productivities are slightly less outside the natural range of cherrybark oak compared to Coastal and Alluvial Plain sites, site index (95 to 105 feet in 50 years) was within bounds for successful growth of cherrybark oak. This study is further evidence that mixed species stands may be more advantageous to develop better log grade in cherrybark oak through crown stratification than pure oak plantations.

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