THE POTENTIAL OF USING COPPICE GROWTH AS TRAINING TREES IN PLANTATIONS FOR THE PRODUCTION OF HIGH-QUALITY OAK BOLES

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Abstract—Oaks (*Quercus* spp.) grown in monoculture plantations often do not develop high-grade boles because all the trees grow at similar rates and crown stratification does not occur resulting in persistent branches and poor bole quality. The use of trainer species in mixed species plantations could promote interspecific competition and crown stratification leading to higher grade oak boles. As part of a larger, long-term study investigating growth, crown interactions, and bole development of cherrybark oak (*Quercus pagoda*) with several species at different planting densities, yellow-poplar (*Liriodendron tulipifera*) and cherrybark oak were planted together. Yellow-poplar has a much faster growth rate and overtops the slower growing cherrybark oak. After four growing seasons at 6- x 6-feet spacing, yellow-poplar averaged 17-feet tall, while cherrybark oak averaged 8-feet tall. Yellow-poplar crowns were overtopping the cherrybark oak. Yellow-poplar was thinned (64 percent of yellow-poplar trees) and allowed to coppice. Two years following the thinning, yellow-poplar coppice growth averaged 4.9-feet tall. This paper reports on yellow-poplar coppice growth and the potential ability of the coppice to have a training effect on the growth, development, and bole form of adjacent cherrybark oaks.

INTRODUCTION

Most hardwood plantations in the southeastern United States have been established and managed as monocultures following the conifer plantation model where growth (volume/weight per unit area) is maximized (Oswalt and Clatterbuck 2011). However, the greatest value of hardwoods is producing high-quality sawtimber (clear wood with minimal defects) rather than just producing fiber (Ashton and Ducey 1996). The conifer plantation model for monocultures promotes uniformity where a single species from similar genetic or geographic sources grow at similar rates with similar sizes. This single species plantation approach does not appear to provide for the development of defect-free, quality hardwood trees similar to those found in mixed species, natural hardwood stands where species stratification occurs. The issue is whether high-quality sawtimber can be produced in plantations of mixed species following natural stand development patterns (Ashton and Ducey 1996, Clatterbuck and Hodges 1988, Larson 1992, Oliver 1982). Many theories, assumptions and suppositions have been suggested such as spatial arrangement, differential growth rates, species tolerance, and varying site productivities to simulate natural stand dynamics in plantations (Kelty 2006). However, few long-term examples of mixed species stand dynamics for hardwood plantations are available in the southern United States to substantiate stand conditions that influence development of a greater volume of clear, knot-free wood (higher quality logs) in plantation settings (Lockhart and others 2012, Oswalt and others 2011).

Afforestation of degraded stands and former agricultural areas has generated increased interest in mixed species plantings as being more environmentally preferable to monocultures, especially in hardwoods (Bristow and others 2006). Mixed species plantings could better simulate development of mixed species natural stands, provide more variety of flora and fauna, and create greater structural forest diversity (Oliver and Larson 1996). Most natural hardwood stands are composed of and developed with mixed species rather than single species monocultures.

The results in this paper are a subset of a much larger research study focused on the growth relationships and species interactions of three species (yellow-poplar (*Liriodendron tulipifera*), black cherry (*Prunus serotina*), and sweetgum (*Liquidambar styraciflua*)) each grown with cherrybark oak (*Quercus pagoda*) at three spacings (6 x 6 feet, 8 x 8 feet, and 10 x 10 feet). Each species mixture by spacing combination was replicated three times in 0.25-acre units (0.20-acre units for the 6- x 6-feet spacing) to evaluate stand development patterns as well as the growth, bole form and grade of cherrybark oak as influenced by these different species and spacings. Preliminary results of cherrybark oak –

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yellow-poplar mixtures at the 6- x 6-feet spacing are presented where 64 percent of the yellow-poplar trees were thinned and allowed to coppice or sprout once the yellow-poplar was overtopping the cherrybark oak. On most productive sites for these species, yellow-poplar will outgrow and overtop slower growing, adjacent cherrybark oak within a few years (Clatterbuck 2011). The purpose is to evaluate the coppice growth of yellow-poplar and its present influence on bole and grade development of cherrybark oak. Will the coppice growth provide a complementary training effect to the cherrybark oak trees or will the coppice growth be great enough to impact the crown expansion and perhaps result in another overtopping of cherrybark oak? Two year coppice data after thinning are presented.

METHODS

Study Site

The study was conducted on the Cumberland Forest, a unit of the University of Tennessee's Forest Resources Research and Education Center (FRREC) in Morgan County, TN. The Cumberland Forest is located in the Wartburg Basin sub-region of the Cumberland Mountains (Smalley 1984). The landscape encompasses high, rugged mountains consisting of narrow crests and long steep slopes often broken with narrow benches and short sandstone cliffs. Small areas of relatively level, smooth land occur on mountain tops, benches, footslopes and stream valleys. The study area is in a narrow, winding valley on one of these footslopes. Elevation averages 1800 feet in the Wartburg Basin. Elevation at the study site is 1350 feet. The soils are Lonewood silt loams, which are fine-loamy, siliceous, semiactive, mesic, Typic Hapludults (National Cooperative Soil Survey 2007). Slopes range from 5 to 12 percent. Site indices range from 70 feet at base age 50 years for shortleaf pine (*Pinus echinata*), white oak (*Quercus alba*), and northern red oak (*Q. rubra*) to 90 feet for yellow-poplar (U.S. Department of Agriculture Natural Resources Conservation Service 2012). The climate is characterized by long, moderately hot summers and short, mild winters (Thornthwaite 1948) Average annual temperature ranges from 34°F in January to 73°F in July with annual average precipitation of 55 to 60 inches that is fairly evenly distributed throughout the year (Smalley 1982).

Planting Design and Establishment

The site was planted during March 2009. The planting design (randomized complete block) was 27 units (3 x 3 x 3) consisting of three species (yellow-poplar, black cherry, and sweetgum) planted with cherrybark oak, three spacings (6 x 6 feet, 8 x 8 feet, and 10 x 10 feet), and three replicates. Each block contained only one spacing such that a block contained three replicates of each species for that spacing (9 units). The 6- x 6-feet units were 0.20 acres each, while the 8- x 8-feet and 10- x 10-feet units were 0.25 acres each. The entire research area was approximately 6.3 acres of planted trees.

Each unit had an odd number of rows. The odd-numbered rows were planted with the competitor species (either yellow-poplar, black cherry, or sweetgum) while the even-numbered rows were planted with alternating competitor species and cherrybark oak with the competitor species always being on the edge of the unit row. Thus eight competitor trees always surrounded a cherrybark oak (fig. 1). An example of the number of trees and rows planted for a 6- x 6-unit (0.20 acre) was 15 rows of 15 trees consisting of 225 total trees, 49 of those trees were cherrybark oak and 176 were the competitor species.

Before Thinning

Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7
O	O	O	O	O	O	O
O	X	O	X	O	X	O
O	O	O	O	O	O	O
O	X	O	X	O	X	O
O	O	O	O	O	O	O
O	X	O	X	O	X	O
O	O	O	O	O	O	O

After Thinning

Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7
O		O		O		O
	X		X		X	
O		O		O		O
	X		X		X	
O		O		O		O
	X		X		X	
O		O		O		O

O = competitor species

X = cherrybark oak

Empty cell = thinned competitor stem

Figure 1—Sample planting and thinning design for mixed species units of cherrybark oak and yellow-poplar (competitor species) before and after thinning of yellow-poplar for the mixed hardwood species stand development research at Morgan County, TN, 2014.

The study site was a former mature eastern white pine (*Pinus strobus*) plantation that was completely harvested in 2001 in anticipation of a southern pine beetle (*Dendroctonus frontalis*) epidemic. The area was maintained through the use of periodic burning and bushhogging for seven years. Little woody vegetation was present. Site preparation consisted of disking during the late fall of 2008 prior to planting. After planting, glyphosate was applied twice during each of the first two growing seasons (2009 and 2010) via a backpack sprayer between the seedling rows to control grasses and other herbaceous vegetation.

After four growing seasons in the 6- x 6-feet yellow-poplar units, the planted yellow-poplar were completely overtopping the planted cherrybark oak. The overhead canopy was closed. We observed that after leaf out during the fifth growing season that yellow-poplar needed to be thinned to allow survival and further growth of the cherrybark oak. Thus, 64 percent of the yellow-poplar trees were thinned manually with a chainsaw on June 5-6, 2013. Every yellow-poplar in the even-numbered rows and every second yellow-poplar in the odd-numbered rows were cut (fig. 1).

Measurements

Survival, total height, and diameter at 4.5 feet (dbh) were measured for every planted tree in the three cherrybark oak – yellow-poplar 6- x 6-feet units (N = 675 trees) after four growing seasons. Two years after the yellow-poplar thinning and six growing seasons after the planting, the same measurements were collected for the unthinned residual trees. Number of sprouts and total height were measured for the 2-year yellow-poplar coppice. Means and standard deviations are presented to give an indication of tree size relationships between species and the variability associated with outplanted seedling regeneration and coppice regeneration.

RESULTS

Yellow-poplar Coppice

Two growing seasons following thinning, yellow-poplar coppice averaged 4.9-feet tall with 4.2 sprouts per stump (table 1). The range of coppice heights was 2 to 7.5 feet. Seven percent of the thinned stumps did not sprout or coppice.

Cherrybark Oak

Four growing seasons after planting, cherrybark oak survival, mean total height and mean dbh were 94 percent, 7.8 feet, and 0.7 inches, respectively. Survival, mean total height, and mean dbh after 6 growing seasons including the last two years after yellow-poplar thinning were 92 percent, 11.7 feet, and 1.1 inches, respectively (table 1).

Yellow-poplar

Survival, mean total height, and mean dbh, of all planted yellow-poplar (491 stems) after four growing seasons were 93 percent, 19.5 feet, and 2.7 inches, respectively (table 1). Two years following thinning, the remaining residual yellow-poplar trees (not thinned –

Table 1—Mean total height and diameters (dbh) with standard deviations (std dev) of planted yellow-poplar and cherrybark oak in mixed species plantings at 6- x 6-feet spacing and mean heights and sprout numbers with standard deviations of coppice yellow-poplar following thinning in 2014, Morgan County, TN

	N	Mean total height (std dev)	Mean dbh[a] (std dev)	Mean sprout number (std dev)
		-------feet-------	-------inches-------	-------#-------
After 4 growing seasons (2009-2012)				
Yellow-poplar	491	19.5 (4.4)	2.7 (1.0)	—
Cherrybark oak	138	7.8 (2.2)	0.7 (0.2)	—
After 6 growing seasons (2009-2014) and 2 growing seasons following thinning				
Yellow-poplar residuals	168	26.0 (3.2)	3.9 (0.5)	—
Cherrybark oak	135	11.7 (2.6)	1.1 (0.3)	—
Yellow-poplar coppice (2013-2014)	294	4.9 (1.4)	—	4.2 (2.0)

— = not applicable

[a] dbh = diameter breast height or 4.5 feet

168 stems) after six growing seasons averaged 26-feet tall and 3.9 inches in diameter. Six residual yellow-poplar (3 percent) trees died in the two years following the thinning. These trees had stem breakage from a windstorm during the summer of 2013.

On average for one 6- x 6-feet yellow-poplar - cherrybark oak mixed planting unit (0.20 acres), the following trees and mean total heights were present after six growing seasons: 56 yellow-poplar trees that were 19.5-feet tall, 45 cherrybark oak that were 11.7-feet tall, and 98 two-year old yellow-poplar coppice stumps with heights of 4.9 feet (table 1).

DISCUSSION

Yellow-poplar with its rapid growth will outgrow most commercial species on well-drained, productive sites in the southeast United States (Beck and Della-Bianca 1981). Height growth rates of 4 feet per year and diameter growth rates of 0.5 inches per year are not uncommon (Brooks 2013, Clatterbuck 2004). Similar growth rates were observed in this study (table 1). O'Hara (1986) reported that yellow-poplar dominated oaks in the Piedmont even when oaks were older, residual trees originating before the disturbance that initiated the stand. Yellow-poplar was chosen as one of the competitor species in the larger study to assess the influence of a faster-growing species on the growth, form, and development of cherrybark oak. Yellow-poplar was assumed to have a greater growth rate and would need to be thinned at some time to allow cherrybark oak to continue to grow and develop. By planting at different spacings, the times until crown closure and overtopping of the cherrybark oak by yellow-poplar could be ascertained. At the 6- x 6-feet narrow spacing (1,210 stems per acre) on the sites of this study, canopy closure occurred after 4 growing seasons. The total average height of yellow-poplar was more than twice of that of cherrybark oak (19.5 feet vs. 7.8 feet, respectively – table 1).

Limited information is available about the capability and growth of yellow-poplar coppice. Most of the present research is for short rotation woody crops for bioenergy or biomass (Rousseau 2015). However, research information is not available on how yellow-poplar might be managed initially to encourage straight, branch-free lower boles of preferred crop trees by regulating crown expansion, then the subsequent influence of coppice after thinning for the continued development (form and pruning) of grade crop trees of cherrybark oak. Although yellow-poplar is known to be a copious seeder that regenerates well naturally (Beck and Della-Bianca 1981), the species also is a dependable, prolific sprouter that outgrows most any species originating from seed or sprouts in natural stands (Beck 1977, McGee and Clark 1975, Vickers and others 2011). In this study, coppice sprouts after two growing seasons from 4-year-old planted yellow-poplars averaged 5-feet tall with 93 percent survival. If the thinning had been conducted during the dormant season prior to leaf out rather than in June during the growing season after leaf out when trees were elongating, growth of yellow-poplar coppice may have been even greater (Smith and others 1997).

Preliminary results suggest that the vigorous coppice of yellow-poplar will influence the development of adjacent oaks. The degree is unknown since these are only two-year growth data since thinning or coppicing. At present growth rates, the yellow-poplar coppice could conceivably become taller (table 1) than the oaks even though the oaks are four years older. However, coppice growth rates usually diminish with age (Smith and others 1997) and interspecific competition with taller and older oaks and yellow-poplar is also expected to influence coppice growth rates.

Meanwhile, only four of the eight competitor yellow-poplar trees surrounding each cherrybark oak were thinned after four growing seasons. These remaining residual trees are growing rapidly and expanding their crowns in response to increased growing space. Although the cherrybark oak is continuing to increase in size, the greater growth of the yellow-poplar residuals is projected to overtop the oak after 7 to 9 growing seasons. The first thinning of the 8- by 8-feet spacing of yellow-poplar and cherrybark oak (not reported in this paper) is also expected within the same time frame. The yellow-poplar thinning of the remaining residuals in the 6- x 6-feet planting and in the 8- x 8-feet units will consist of trees that will average 6 inches dbh, allowing some potential income after 7 to 9 years of growth if small-diameter biomass markets are available. The remaining stand will consist of the cherrybark oak trees and two sets (ages) of yellow-poplar coppice following the coppice-with-standards system described by Smith and others (1997). Without the thinning, oaks would succumb to the faster-growing yellow-poplar. Without the influence of the yellow-poplar coppice, resulting oak form, pruning, and subsequent grade would be diminished.

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