TWENTY-NINE YEARS OF DEVELOPMENT IN PLANTED CHERRYBARK OAK-SWEETGUM MIXTURES: IMPLICATIONS FOR FUTURE MIXED-SPECIES HARDWOOD PLANTATIONS

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ABSTRACT

Results from a long-term planted mixture of cherrybark oak (*Quercus pagoda* Raf.) and sweetgum (*Liquidambar styraciflua* L.) showed sweetgum taller in height and larger in diameter than cherrybark oak early in plantation development. By age 17, cherrybark oak was similar in height and diameter with sweetgum and by age 21 was taller in height and larger in diameter than sweetgum depending on spacing arrangement. By age 29, cherrybark oak was competing with other cherrybark oak in the overstory canopy. The ascendance of cherrybark oak above sweetgum in intimate plantation mixtures confirms results from bottomland hardwood stand development in natural stands. Future bottomland hardwood mixed-species plantation research must include stand-level replication. Further, pure plantings of each species in the mixture are necessary to compare development to the planted mixture.

INTRODUCTION

Planting tree species mixtures is gaining in popularity as we begin to understand their benefits to the functions and values of forests. Benefits, compared to single-species plantations, include greater species and structural diversity (Twedt and Wilson 2002), development of a higher quality timber tree due to the influence of interspecific competition early in stand development, and greater timber yield (Binkley 1984, Kelty 1986). Greater timber yield in mixed-species plantations may occur due to more efficient use of growing space as species stratify into different canopy layers (Kelty 1986).

Few long-term examples exist of mixed-species plantation development in southern bottomland hardwoods. Instead, we have had to rely on field observations of developmental dynamics in natural stands (Bowling and Kellison 1983, Clatterbuck and Hodges 1988, Johnson and Krinard 1988) to develop mixed-species planting strategies. The primary objective of this study was to determine the long-term height and diameter growth patterns in artificial mixtures of cherrybark oak (*Quercus pagoda* Raf.) and sweetgum (*Liquidambar styraciflua* L.) planted at different spacings. Twenty-nine year results are presented.

METHODS

SITE

The study is located on the Noxubee National Wildlife Refuge in Oktibbeha County, MS (33° 18' N, 88° 44' W). The site is a low terrace adjacent to the active floodplain of the Noxubee River. Soil is a Stough fine sandy loam (coarse-loamy, siliceous, semiactive, thermic Fragiaquic Paleudults) which is considered marginal for cherrybark oak and sweetgum (SI50 = 80 to 85 feet using the Baker and Broadfoot System; Baker and Broadfoot 1979) because of the presence of a fragipan. The climate is described as warm and humid (Brent 1973). Average annual rainfall is 50.8 inches, ranging from 6.1 inches in March to 2.5 inches in October. Average annual temperature is 64° F, ranging from 81° F in July to 46° F in January. Prior to planting, the site was used for grazing and hay production.

PLANTING DESIGN AND ESTABLISHMENT

Three spacing arrangements were used in the study. The first spacing involved planting mixtures of cherrybark oak and sweetgum on an 8 by 8 foot spacing (8x8). This spacing was the acceptable plantation spacing for trees in the southern United States in the early 1980s. The first row in this spacing arrangement was planted in sweetgum (see Lockhart and others 2006 for a diagram of the spacing arrangement), with cherrybark oak and sweetgum seedlings alternated on the second row; the third row was also planted in sweetgum. This arrangement resulted in each cherrybark oak seedling being surrounded by eight sweetgum seedlings. A total of 35 cherrybark oak seedlings and 188 sweetgum seedlings were planted in seven rows (three rows were alternating cherrybark oak and sweetgum seedlings), excluding buffer trees. This spacing arrangement is equivalent to

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108 cherrybark oak seedlings per acre and 572 sweetgum seedlings per acre.

The second spacing arrangement involved planting mixtures of cherrybark oak and sweetgum on a 5 by 5 foot spacing (5x5) using the same row design as the 8x8 described above. The closer spacing was chosen based on previous work in natural stands of cherrybark oak and sweetgum (Clatterbuck 1985). A total of 45 cherrybark oak seedlings and 168 sweetgum seedlings were planted in 11 rows (five rows alternating cherrybark oak and sweetgum seedlings). This spacing arrangement is equivalent to 367 cherrybark oak seedlings per acre and 1,372 sweetgum seedlings per acre.

The third spacing arrangement involved planting mixtures of cherrybark oak and sweetgum on a 5 by 5 foot similar to the 5x5 except two rows of sweetgum were planted on each side of the alternating cherrybark oak and sweetgum row (5x5D) for a total of 14 sweetgum seedlings surrounding each cherrybark oak seedling. This arrangement was used to provide greater interspecific competition in case the first row of sweetgum was quickly overtopped. A total of 27 cherrybark oak and 182 sweetgum seedlings were planted in 11 rows (three rows alternating cherrybark oak and sweetgum seedlings). This spacing arrangement is equivalent to 225 cherrybark oak seedlings per acre and 1,517 sweetgum per acre.

The site was disced prior to planting. Seedlings were then planted in March 1982. Cherrybark oak seedlings were 2-0 stock produced in a nursery at the Blackjack Research Facility on the Mississippi State University campus (about 15 miles from the study site). Sweetgum seedlings were 1-0 stock purchased from a private nursery. Thirty-six cherrybark oak seedlings (34 percent of the total number of cherrybark oak planting spots) were replanted with 1-0 stock following first-year mortality with the 2-0 stock. Periodic mowing was conducted within and between rows during the first two growing seasons following planting.

MEASUREMENTS

Height and diameter measurements were conducted following the 1989, 1991, 1998, 2002, and 2010 growing seasons (stand ages 8, 10, 17, 21 and 29, respectively). Tree height was measured with a height pole in 1989 and 1991, a laser height instrument in 1998 and 2002, and a clinometer in 2010. Diameter (d.b.h., 4.5 feet above ground) was measured with a standard diameter tape. In 2002 and 2010, crown classes (dominant, codominant, intermediate, and overtopped) were assigned for each tree based on the tree crown's position and condition (Meadows and others 2001).

ANALYSES

Statistical analyses were conducted using PC-SAS. Each cherrybark oak and surrounding sweetgum was considered an experimental unit. Survival was calculated as the number of trees alive at each measurement time, including replanted cherrybark oak seedlings. Sweetgum height and diameter within each cherrybark oak plot were averaged and compared with cherrybark oak using repeated-measures analysis. The Wilks' Lambda test was used to test the effect of time and time by species interactions. Only those plots with a live cherrybark oak following the 2010 measurements were included in all analyses. An alpha level of 0.05 was used to determine statistical significance.

RESULTS

SURVIVAL

Survival across all spacings was 73 and 97 percent for cherrybark oak and sweetgum, respectively. Cherrybark oak survival following the 2010 growing season ranged from 86 percent in the 8x8 to 62 percent in the 5x5, while sweetgum survival was nearly 100 percent across all spacings (table 1). Much of the cherrybark oak mortality occurred prior to the 1989 measurements.

HEIGHT

Height differences of 11 to 18 feet, depending on spacing, existed between cherrybark oak and sweetgum by 2002 (fig. 1). Time and time by species interactions were different across all spacings ($p \leq 0.01$ within each spacing) indicating that while both species grew in height over time, their patterns of height growth differed. During 1989 and 1991 sweetgum was taller than cherrybark oak within each of the 3 spacings ($p \leq 0.05$). Seventeen years after planting (1998), no height differences existed among the 3 spacings ($p \geq 0.08$). By 2002, cherrybark oak was taller than sweetgum in the 8x8 ($p = 0.02$) and 5x5D ($p=0.02$), but similar in height in the 5x5 ($p = 0.14$). Following the 2010 growing season, cherrybark oak was much taller than sweetgum within each spacing ($p < 0.01$).

DIAMETER

Cherrybark oak and sweetgum diameter development patterns were similar to their respective height development patterns (table 2). At the time of the 1989 and 1991 measurements, sweetgum was larger in diameter than cherrybark oak in the 8x8 and 5x5, while the two species had similar diameters in the 5x5D. Cherrybark oak and sweetgum had similar diameters within each spacing by age 17 (1998). Afterwards, cherrybark oak diameters were considerably larger than sweetgum.

CROWN CLASSES

A majority of the cherrybark oak crowns were in the dominant or codominant position at the time of the 2010 measurements (table 3). No sweetgum crowns were classed as dominant and only one percent were considered codominant. A majority of the sweetgum crowns were overtopped in the 5x5 and 5x5D while 99 percent of the sweetgum crowns in the 8x8 were intermediate or overtopped.

DISCUSSION

STAND DEVELOPMENT

Lockhart and others (2006) previously reported the ascendance of cherrybark oak above sweetgum by age 21 followed natural stand development patterns of cherrybark oak-sweetgum stratification. Planted sweetgum dominated cherrybark oak during the early years of stand development in each of the three spacings. But sweetgum height and diameter development slowed during the stem exclusion stage of stand development, with cherrybark oak eventually overtopping sweetgum. By age 17, cherrybark oak had either caught or passed sweetgum in height and diameter, depending on spacing, and was significantly taller in height and larger in diameter by age 21. Differences in height and diameter were further accentuated by age 29. By 2010, the codominant cherrybark oaks were competing with other cherrybark oaks in the overstory canopy, while sweetgum either slowed in height growth (8x8) or had no increases in height (5x5 and 5x5D). A similar pattern of oak stratification has been documented in cherrybark oak-sweetgum mixtures in natural stands (Clatterbuck and Hodges 1988), bottomland red oak [cherrybark oak, water oak (Q. nigra L.), and willow oak (Q. phellos L.)]-sweetgum-American hornbeam (Carpinus carolinana Walt.) mixtures in Arkansas and Mississippi (Bowling and Kellison 1983, Johnson and Krinard 1988), and northern red oak (Q. rubrum L.)-red maple (Acer rubra L.)-black birch (Betula lenta L.) mixtures in the northeastern United States (Oliver 1978).

Results from this study indicate that cherrybark oak, planted in intimate mixtures with sweetgum, develops similarly to bottomland red oak-sweetgum mixtures in natural stands (Bowling and Kellison 1983, Clatterbuck and Hodges 1988, Johnson and Krinard 1988). Best individual cherrybark oak development occurred at the 8x8. These trees were taller in height and larger in diameter compared to cherrybark oaks in the 5x5 and 5x5D. Sweetgum in the 8x8 did reach a pulpwood merchantability standard (4 inches d.b.h.) before being overtopped by cherrybark oak. Therefore, we recommend that planting intimate mixtures of cherrybark oak and sweetgum be conducted on 8 by 8 foot spacings. A 10 by 10 foot spacing would probably be acceptable.

FUTURE RESEARCH

The present study represented a case study of cherrybark oak and sweetgum stand development in intimate mixtures. A scientifically rigorous study is needed to fully explore the cause and effect of different species mixtures in bottomland hardwood plantation development, especially when the objective is long-term quality sawtimber production and wildlife habitat. Several weaknesses in the present study include the lack of stand-level replication within and among the different plantation spacings. Further, replicated pure plantings of each species are necessary to serve as a baseline to compare stem and stand level growth. An example mixed-species plantation design is shown in fig. 2. An 8-acre treatment plot, using one designated tree spacing arrangement, is split into four 2-acre subplots. Two of the subplots would contain a pure planting of each species, assuming a two-species mixture is used. The third subplot would contain pure rows of each species such that Row 1 would contain species a, Row 2 would contain species b, row 3 would contain species a and so forth. Our experience is that planters would rather plant pure rows of a species to simplify the planting operation. While efficient, this design does not eliminate early intraspecific competition as trees within a row will be competing with others of the same species. The fourth subplot would contain a planting design based on known or observed stand development patterns, similar to those used in the present study. Possible bottomland hardwood species mixtures can be developed from Lockhart and others (2008). Ideally, four or five replicates of this treatment plot would be needed to adequately test bottomland hardwood mixed-species plantation development.

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Table 1—Survival of cherrybark oak and sweetgum planted in mixture at three spacing arrangements in Oktibbeha County, MS

Spacing	Species	n	1989	1991	1998	2002	2010
feet			----------percent----------				
8 x 8	cherrybark oak	35	89	89	89	89	86
	sweetgum	138	100	100	100	100	100
5 x 5	cherrybark oak	45	82	82	82	80	62
	sweetgum	168	100	100	100	99	92
5 x 5D	cherrybark oak	27	78	78	78	78	70
	sweetgum	182	99	99	99	99	98

Table 2—Diameter (dbh, 4.5 feet) of cherrybark oak and sweetgum planted in mixture at three spacing arrangements in Oktibbeha County, MS. Values in parentheses represent one standard error

Spacing	Species	1989	1991	1998	2002	2010
feet		----------inches----------				
8 x 8	cherrybark oak	1.8 (0.1)	2.8 (0.2)	5.5 (0.3)	7.0 (0.4)	9.3 (0.6)
	sweetgum	2.4 (<0.1)	3.4 (0.1)	5.1 (0.1)	5.6 (0.1)	6.3 (0.1)
p-value		< 0.01	< 0.01	0.33	< 0.01	<0.01
5 x 5	cherrybark oak	1.0 (0.1)	1.6 (0.1)	3.4 (0.4)	4.5 (0.5)	7.3 (0.9)
	sweetgum	1.2 (0.1)	2.0 (0.1)	3.1 (<0.1)	3.3 (<0.1)	3.6 (0.1)
p-value		0.01	0.02	0.45	0.04	< 0.01
5 x 5D	cherrybark oak	1.1 (0.1)	1.7 (0.1)	3.7 (0.4)	5.0 (0.6)	7.3 (0.9)
	sweetgum	1.2 (0.1)	1.9 (0.1)	3.1 (0.1)	3.3 (<0.1)	3.5 (0.1)
p-value		0.085	0.14	0.11	0.01	< 0.01

Table 3—Percent of trees by crown class following the 2012 growing season for cherrybark oak and sweetgum planted in mixture at three spacing arrangements in Oktibbeha County, MS

Spacing	Species	Dominant	Co-dominant	Intermediate	Overtopped
feet		----------percent----------			
8 x 8	cherrybark oak	4	78	7	11
	sweetgum	0	1	46	53
5 x 5	cherrybark oak	17	46	10	27
	sweetgum	0	0	3	97
5 x 5D	cherrybark oak	28	38	17	17
	sweetgum	0	0	22	78

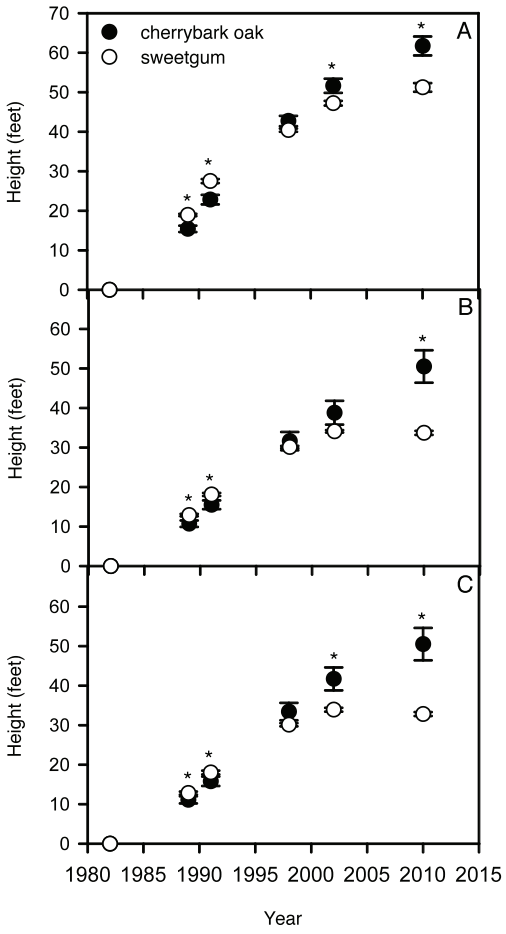

Figure 1—Height development of cherrybark oak and sweetgum planted in mixtures at three spacing arrangements in Oktibbeha County, MS. (A) 8 by 8 foot spacing; (B) 5 by 5 foot spacing; (C) 5 by 5 foot spacing with two rows of sweetgum. Asterisks indicate difference at $p \leq 0.05$. Bars represent one standard error.

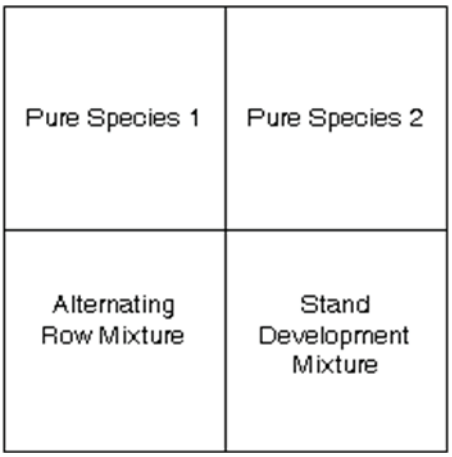

Figure 2—Example bottomland hardwood mix-species research design.