EFFECTS OF DISKING, BEDDING, AND SUBSOILING ON SURVIVAL AND GROWTH OF THREE OAK SPECIES IN CENTRAL MISSISSIPPI

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Abstract—A replicated split-plot design experiment to evaluate the effects of three site preparation methods (disking, bedding, and subsoiling plus bedding) on survival and growth of three oak species (cherrybark, *Quercus pagoda* Raf.; Shumard, *Quercus shumardii* Buckl.; and Nuttall, *Quercus texana* Buckl.) was established in 1994 in Madison County, MS. The study site was an abandoned agricultural field on a terrace of the Pearl River consisting of poorly drained, fragipan soils often saturated during wet periods and winter months. Differences among species for first and tenth year survival were statistically significant and were 92 and 79 percent for Nuttall, 95 and 66 percent for Shumard, and 85 and 60 percent for cherrybark. Tenth year diameter at breast height (d.b.h.) and height trends were similar for the three species within site preparation methods. Nuttall outperformed cherrybark and Shumard, but showed no significant differences for site preparation methods. In the driest replication, cherrybark and Shumard significantly benefited from the subsoiling plus bedding treatment, but bedding was not consistently significantly different from disking. It is believed that the use of a D6 Caterpillar® bulldozer and Symonds Blade Plow may have had a negative impact on soil compaction and growth in the two wettest replications.

INTRODUCTION

In recent years, there has been an increasing trend in the conversion of abandoned agricultural land to forestland in the Southern United States (Munn and Evans 1998). Data compiled for the 1992 Resource Planning Act by the USDA Forest Service Forest Inventory Analysis (FIA) indicates that 5.7 percent of agricultural land was converted to forestland in the southern region between 1984 and 1992. This was the largest conversion of land from one use to another reported in the study. Twenty-five million acres of cropland in the Southeastern United States is estimated to be converted to some type of forest land by the year 2040 (Wear and Greis 2002), and the potential for these sites to be afforested with hardwoods is considerable (Ezell and others 2007). Seedling quality, planting quality, species suitability to soil and site type, site preparation, and herbaceous weed control are important factors that must be addressed to insure hardwood seedling survival and adequate growth.

Cropland preparation, prior to the introduction of no-till planting equipment, was typically done by plowing, disking, and dragging with a tractor each spring before planting. These site preparation techniques increase soil compaction and lead to the development of plow pans. The presence of these pans and naturally occurring fragipans can restrict deep root development and drainage creating poor conditions for woody crop establishment. Soil compaction resulting from machine traffic can decrease soil aeration porosity and reduce root growth, water and air movement, and solute diffusion (Scott and others 2004). Ezell and Shankle (2004) observed a significant increase in first year height and groundline diameter of Shumard oak (*Quercus shumardii* Buckl.), water oak (*Quercus nigra* L.), willow oak (*Quercus phellos* L.), and green ash (*Fraxinus pennsylvanica* Marsh.) species from subsoiling a retired agricultural site. Fallis and Duzan (1994) reported an increase from the effects of subsoiling on soils with big stone and fragment content on initial survival and 19 year height and basal area of loblolly pine (*Pinus taeda* L.).

The objective of this study was to analyze the effect of disking, bedding, and subsoiling plus bedding on the survival and growth of four commercially important oak species planted on a typical poorly drained retired agricultural field in central MS.

MATERIALS AND METHODS

The study was established in 1994 on a 63 acre farm that was donated to Mississippi State University through the John and Jane Player Endowment. The land is situated on a terrace in the Pearl River bottom in Madison County, MS. This area, typical of rural MS, was homesteaded and farmed for decades before retirement. The silty loam textured Bude and Providence soils series (Scott 1984) of the study site possess fragipans and along with the site's agricultural history are characteristic of many bottomland agricultural sites in MS. Fragipan depth was measured with a penetrometer and varied among the fields. Three study replications (labeled one, two, and three) were selected to account for differences in fragipan depth and extent plus year round soil moisture. The fragipan in replications one and two extended 23 inches from the surface to 60 inches deep, and the fragipan in replication three extended 19 inches from the surface to 31 inches deep. Replication one was considered the wettest area; replication two was slightly elevated and was the driest area; and replication three was intermediate in soil moisture. On this relatively flat site (0 to 2 percent slope), the fragipans restrict drainage causing soil saturation in the winter or wet periods in addition to presenting a physical barrier to root penetration. The site is not subject to regular inundation from flood waters.

The study was installed as a replicated split-plot design with site preparation methods representing main plots and species representing sub-plots. Main plot site preparation methods consisted of disking (D), bedding (B), and subsoiling plus bedding (SB). Prior to implementing the three site preparation treatments, the entire site was disked to help

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control competing vegetation. Site preparation treatments on the main plots were applied in blocks of rows that were 13 feet apart on centers and were randomly assigned within a replication. A disk harrow, bedding plow, and Symonds Blade Plow pulled by a D6 Caterpillar® bulldozer were used to apply the D, B, and SB treatments, respectively. The blade plow, manufactured by Symonds Australia, Inc., cut a subsoil trench 30 inches deep and mounded beds 18 inches high directly over the trench. Soil was neither extremely dry nor wet during the October site preparation.

Nuttall (*Quercus texana* Palmer), water, Shumard, and cherrybark (*Quercus pagoda* Raf.) 1-0 oak seedlings were acquired from Scott Paper Company's (now Molpus Timberland) nursery in Elberta, AL, and planted in January 1994 with planting shovels in randomized species subplots within main plot site preparation blocks. These species were selected because of their commercial value and differences in drainage preference. Water oak seedling roots were dry upon arrival from the nursery, and this resulted in poor survival and their ultimate removal from the study. Seedling root collar diameters and heights were not measured prior to planting, but seedlings were sorted across species for comparable size. A total of 804 cherrybark, Shumard, and Nuttall seedlings were planted on 13 by 13 foot spacing in three species blocks per three site preparation plots per three replications, approximately 30 trees per species block. The number of trees planted varied slightly across replications one, two, and three (279, 288, and 237) because of the irregular shape of the old agricultural fields. There were no prolonged dry periods during the 1994 growing season, and moisture conditions were deemed adequate for survival.

Herbaceous weed control was performed manually using directed spray from backpack sprayers prior to planting and every year following planting. Beds were treated with 4 pounds active ingredient per acre Simazine® each year during the 10 year study period in late January/early February to inhibit the germination of weed seed. During the growing season, competing vegetation was controlled with 48 ounces of Roundup® per acre in four foot strips within rows. Areas between rows were mowed several times during the growing season.

Differences among replications, site preparation methods, species, and interaction terms for first year survival (taken at the beginning of the second growing season) and tenth year survival, d.b.h. and height were analyzed with SAS GLM (SAS 1999) using a completely fixed effect, replicated split-plot model. An arcsine transformation was applied to subplot mean percent survival data. In addition to an analysis of variance of the entire study design, separate analyses were conducted by individual study replications, site preparation methods, and species.

RESULTS AND DISCUSSION

Survival

Species differed significantly for both first year and tenth year survival (table 1). First year survival averaged across replications and site preparation methods ranged from 85 percent for cherrybark and 92 percent for Nuttall to 95 percent for Shumard. Tenth year survival ranged from 60 percent for cherrybark and 66 percent for Shumard to 79 percent for Nuttall. Neither species-by-site preparation method nor species-by-replication interactions were significant. The replication-by-site preparation method interaction was significant for first year survival only. Analysis of variance by replication did not reveal any patterns that could be explained on the basis of replication wetness or the effect of site preparation method on soil moisture.

First year survival for the three hardwood species was comparable to that reported in a study of the effects of herbaceous weed control on oak seedling survival (Ezell and others 2007). Ezell and others (2007) demonstrated a 20 to 44 percent increase in first year oak seedling survival in herbicide treatment areas versus non-treatment areas. The complete control of competing vegetation in our study may have had more influence on first year survival than treatments that related to soil moisture. Some rodent and mechanical damage was noted between years one and ten, but it was scattered in occurrence and minimal. After 10 years, there were still no significant survival differences due to site preparation methods or replications. Cherrybark, which prefers the better-drained bottomland soils of the three species (Harlow and others 1979), exhibited the lowest tenth year survival at 60 percent (a loss of 25 percent from first year survival). Nuttall, known for rapid growth on poorly drained clay soils (Hardin and others 2001), had the highest survival at 79 percent (a loss of 13 percent from first year survival). Shumard, which is usually found on terraces in minor stream flood plains (Hardin and others 2001), had a tenth year survival of 66 percent (a loss of 29 percent from first year survival).

Tenth Year D.b.h. and Height

All first-order and second-order interaction terms for replications, site preparation methods, and species were significant for tenth year d.b.h. and height (table 1); therefore, separate analyses were conducted for each factor and level. The significant interaction terms imply that the differences among species for d.b.h. and height vary with site preparation method and replication. Average diameters and heights for the separate analyses and their significance are given in table 2. The expected response was an increase in d.b.h. and height on the wettest replication (one) as the intensity of site preparation increased from D to SB and a diminishing difference as the replications decreased in wetness.

Table 1—Analysis of variance[a] for first year survival and tenth year survival, d.b.h., and height variables in the replicated split plot design site preparation method-oak species study in Madison County, MS, where site preparation methods are main plots and species are subplots

		Measurement traits							
		First year survival (%)[b]		Tenth year survival (%)[b]		Tenth year d.b.h. (in)		Tenth year height (ft)	
Source of variation	DF	MS	F-test[cd]	MS	F-test[cd]	MS	F-test[cd]	MS	F-test[cd]
Replication (Rep)	2	0.046	3.27	0.075	1.76	9.56	7.92**	406.36	22.82**
Site prep (SP)	2	0.008	0.55	0.006	0.14	1.36	1.13	5.05	0.28
Rep x SP	4	0.092	6.56**	0.010	0.24	14.08	11.67**	218.79	12.29**
Species (SC)	2	0.065	4.68*	0.188	4.38*	77.73	64.42**	1184.91	66.55**
Rep x SC	4	0.007	0.50	0.077	1.79	3.47	2.88*	85.15	4.78**
SP x SC	4	0.021	1.51	0.030	0.71	5.78	4.79**	104.42	5.86**
Rep x SP x SC	8					3.47	2.88**	111.09	6.24**
Error	528					1.21		17.81	
Error (subplot)[b]	8	0.014		0.043					

[a] Model is completely fixed effects.
[b] Survival was calculated on a percentage of subplot means using the arcsine transformation.
[c] * = significant at the 0.05 level.
[d] ** = significant at the 0.01 level.

The three species yielded similar trends across site preparation method-by-replication combinations; however, differences among means were not always significant. In general on the two wettest replications (one and three), d.b.h. and heights were lower for the SB treatment than for the less intensive D and B treatments. Cherrybark d.b.h. and height were significantly lower (table 2) for the SB treatment. Cherrybark averaged 4.2 inches d.b.h. and 24.6 feet in height for the D treatment and 2.2 inches d.b.h. and 15.5 feet in height for the SB treatment. Even though soils were not noticeably wet during site preparation, the weight and soil disturbance of the D6 Caterpillar® bulldozer and Symonds Blade Plow used to implement the SB treatment may have compacted soils, compared to the D and B treatments. Compaction could have contributed to lower SB treatment growth.

Significant differences in cherrybark and Shumard d.b.h. and heights for the driest replication (two) support the expected response of increased growth with increasing site preparation intensity. Bedding alone (B) did not always give a significant increase in growth over disking (D), but subsoiling and bedding (SB) provided a 39 percent d.b.h. and 37 percent height increase over disking (D) for cherrybark (table 2). If soil compaction were a factor in growth, the weight and soil disturbance of the bulldozer and blade plow may have had less of an effect on the drier replication. Significant differences for Shumard occurred only in replication two. The SB site preparation treatment outperformed the D (by 45 percent d.b.h. and 39 percent height) and B (by 14 percent d.b.h. and 19 percent height) treatments.

Height means among site preparation methods were significantly different for Nuttall in replication three (intermediate in wetness), but the differences among site preparation means were very small. This result can be explained by Nuttall's unusually high survival in this replication and the subsequent higher degrees of freedom in the denominator of the F-test. In general, tenth year Nuttall d.b.h. and height were not significantly affected by site preparation method or replication.

Table 2—Tenth year average diameter and height by study replication (Rep), species, and site preparation method for three oak species planted in Madison County, MS

Rep	Pan depth/ wetness	Oak species	Site preparation method[a]	Tenth year average d.b.h (in)[bc]		Tenth year average Height (ft)[bc]	
1	23-60 in Wettest	Cherrybark	D	4.2	A	24.6	A
			B	3.8	A	22.9	A
			SB	2.2	B	15.5	B
			Combined mean	3.7**		22.4**	
		Shumard	D	3.9		21.4	
			B	3.6		23.3	
			SB	3.6		22.5	
			Combined mean	3.7		22.5	
		Nuttall	D	5.4		27.6	
			B	4.8		26.1	
			SB	4.8		27.6	
			Combined mean	5.0		27.1	
2	23-60 in Driest	Cherrybark	D	3.1	A	18.1	A
			B	3.9	B	21.0	A
			SB	4.3	B	24.8	B
			Combined mean	3.7**		21.0**	
		Shumard	D	2.9	A	17.9	A
			B	3.7	A	21.7	B
			SB	4.2	B	25.9	C
			Combined mean	3.6**		21.2**	
		Nuttall	D	4.8		25.1	
			B	4.2		22.7	
			SB	4.6		23.9	
			Combined mean	4.6		24.1	
3	19-31 in Intermediate	Cherrybark	D	3.2	B	18.6	
			B	4.0	A	20.8	
			SB	2.9	B	18.0	
			Combined mean	3.4*		19.0	
		Shumard	D	3.0		18.7	
			B	3.3		17.8	
			SB	2.7		17.1	
			Combined mean	2.9		18.0	
		Nuttall	D	4.6		24.9	A
			B	4.2		23.0	B
			SB	4.3		24.3	AB
			Combined mean	4.4		24.1*	

[a] Site preparation method: D = disked, B = bedded, and SB = subsoiled and bedded.
[b] * = significant at the 0.05 level; ** = significant at the 0.01 level; indicates significant differences among site preparation methods within species and replication.
[c] A, B, C = Duncan's multiple range test groupings; means with the same letter are not significantly different.

CONCLUSIONS

Nuttall oak planted on a poorly drained retired agricultural field in a river bottom terrace in Madison County, MS, was superior in tenth year survival and growth to cherrybark and Shumard oaks. Nuttall d.b.h. and height means were not significantly different for disking, bedding, or subsoiling plus bedding site preparation treatments, but it performed well in all three replications that varied in degree of year round wetness. Differences among species for first and tenth year survival were statistically significant and were 92 and 79 percent for Nuttall, 95 and 66 percent for Shumard, and 85 and 60 percent for cherrybark. First year survival varied significantly for site preparation method-by-replication but not in a pattern that could be readily explained by species soil moisture preference or drainage improvement.

Tenth year d.b.h. and height growth trends for site preparation methods were similar for the three species. In the driest replication, cherrybark and Shumard significantly benefited from the subsoiling plus bedding (SB) treatment, but bedding (B) was not consistently significantly different from disking (D). The principal effect of the subsoiling plus bedding (SB) treatment on d.b.h. and height may have been largely due to subsoiling, since the bedding (B) alone treatment was only sometimes significantly different from disking (D).

In the wettest replication, disking (D) was superior to bedding (B) and subsoiling plus bedding (SB), but cherrybark was the only species where d.b.h. and height were significantly different for the treatments. This ranking of site preparation methods was opposite to that in the driest replication. It is believed that the use of a D6 Caterpillar® bulldozer and Symonds Blade Plow to implement the SB treatment may have had a negative impact on soil compaction and growth in the two wettest replications.

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