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A Guide for Matching Oak Species with Sites during Restoration of Loess-influenced Bottomlands in the West Gulf Coastal Plain

THE UNIVERSITY of TENNESSEE
INSTITUTE of AGRICULTURE

A Guide for Matching Oak Species with Sites during Restoration of Loess-influenced Bottomlands in the West Gulf Coastal Plain

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***Precautionary statement**: The results of this work may not apply for all bottomland sites in the entire hardwood range. The natural range of some of the species studied (e.g., Nuttall, bur and swamp white oaks) either ceases at or marginally extends into the West Gulf Coastal Plain physiographic region (Burns and Honkala, 1990). Users should seek localized knowledge of the silvics of each species before incorporation into bottomland restoration regimes. The hydrology in some bottomland sites may have been altered due to cultivation or change in flooding regime from impoundments or artificial drainage, thus conditions may be better or more poorly drained than soil mottling might suggest. The naturally occurring dark colors in some soils may mask mottling to individuals without extensive soil knowledge.*

Abstract

This guide has been prepared for natural resource professionals, both private and public, who advise on, develop and/or implement tree-planting plans to restore bottomland oak forests. Private landowners with advanced knowledge of forest management practices may find the guide helpful as well. Users will acquire information on matching 10 common bottomland hardwood species to different hydric soils based on *soil mottling*, specifically the *gleyed matrix*. *Soil mottling* and the presence of a *gleyed matrix* are important determinants when predicting high groundwater conditions and the resulting survival and growth of bottomland oaks. The findings suggest that practitioners plant Nuttall, pin and overcup oaks in poorly drained soils. As the drainage improves, begin mixing in willow oak. In the best-drained soils (if they exist), finish by including water, swamp chestnut, swamp white, Shumard, cherrybark and bur oaks. Potential species diversity should expand as the soil drainage improves.

Introduction

Over the past several decades, federal incentive programs have encouraged the restoration of bottomland forests throughout the West Gulf Coastal Plain (WGCP) and the Lower Mississippi Alluvial Valley (LMAV). Programs such as the Conservation Reserve (CRP) and Wetlands Reserve (WRP) have been marginally successful (Stanturf et al., 2001). Foresters and contractors often follow conventional tree-planting procedures that are well-established for upland sites, but prove problematic in bottomlands. High water tables, soil drainage and compaction, overland flooding and diverse soil properties make species selection difficult. Slight changes in topography and soil structure often have a dramatic effect on survival and growth of planted oak seedlings (Hodges and Switzer, 1979). This project documented the survival and growth of 6-year-old seedlings that were established on a bottomland site in 2004, located at the West Tennessee Research and Education Center, Jackson, Tennessee. This site is adjacent to the South Fork of the Forked Deer River and periodically floods. The alluvial deposits are a result of erosion of the local silty-loess uplands and the underlying Coastal Plain.

The purpose of the project was to determine how soil drainage as indicated by mottling (specifically, the point of >50 percent gray color throughout the soil profile) affects the survival and growth of bottomland oak species. The findings are provided as a guide to aid practitioners with bottomland hardwood restoration efforts.

Species Examined

A variety of species can be planted in bottomland restoration projects. However, due to their economic and ecological values, this project focused on only bottomland oaks. The natural range of 10 bottomland oaks overlaps (or slightly extends into) the study region in West Tennessee. Only eight species were available from nurseries at the time of establishment. Those eight included:

Red Oak Group

Water oak	(*Quercus nigra*)
Willow oak	(*Quercus phellos*)
Pin oak	(*Quercus palustris*)
Nuttall oak	(*Quercus nuttallii*)
Shumard oak	(*Quercus shumardii*)

White Oak Group

Overcup oak	(*Quercus lyrata*)
Swamp chestnut oak	(*Quercus michauxii*)
Swamp white oak	(*Quercus bicolor*).

The two other oak species that were not available for this work include:

Red Oak Group

Cherrybark oak	(*Quercus pagoda*)

White Oak Group

Bur oak	(*Quercus macrocarpa*)

These latter two species are inserted into the recommendations based on silvicultural information made available through the work of other scientists. For information regarding the identification of bottomland oaks, refer to *Identifying Oak Trees Native to Tennessee* (Mercker et al., 2006).

Soil Mottling and Gleyed Matrix Explained

Highest groundwater levels and water table fluctuations are routinely estimated by soil scientists using soil morphology, primarily the soil color. Gray colors are associated with saturated soil environments. *Soil mottling* and the presence of a *gleyed matrix* are important determinants when predicting high groundwater conditions and the resulting survival and growth of bottomland oaks. Further explanation of these terms follows.

> **Soil mottling** – occurs when gray or black colors become mixed with the normal red, brown or yellow soil colors; gray and black colors indicate that periods of soil saturation are frequent.
>
> **Gleyed matrix** – occurs when water is removed very slowly and the soil is saturated for three or more months; the gleyed matrix is the point where gray mottling becomes so excessive that gray colors exceed 50 percent of the soil profile.

The color of a soil and its location within the soil profile can indicate the typical drainage conditions over time. A gray soil color, for example, occurs after prolonged saturation. Soil color is affected primarily by organic matter content and the presence of iron and manganese (Soil Survey Division Staff, 1993). The colors present within a soil horizon are described by comparison with color charts. The color chart most commonly used to describe soil color is a segment of the Munsell Soil Color Chart (Munsell, 2000) that consists of systematically arranged pages of colored squares, or chips (Figure 1). The color chips are arranged by color hue, value and chroma. **Hue** refers to principle spectral colors such as yellow (Y), red (R) and their intermediate midpoints, such as yellow-red (YR). **Value** describes the lightness or darkness of a color from black (0) to white (10). **Chroma** refers to the relative purity or dullness of a color, ranging from the purest colors (8) to the most neutral colors (0). Color hue, value and chroma are combined in a numerical expression to form a designation for each color chip. For example, a color chip having a designation of 10 YR 4/2 has a hue of 10 YR, a value of 4 and a chroma of 2. The dominant color in a soil horizon is referred to as the soil matrix color and the contrasting colors, or areas marked with spots of color, are referred to as mottles.

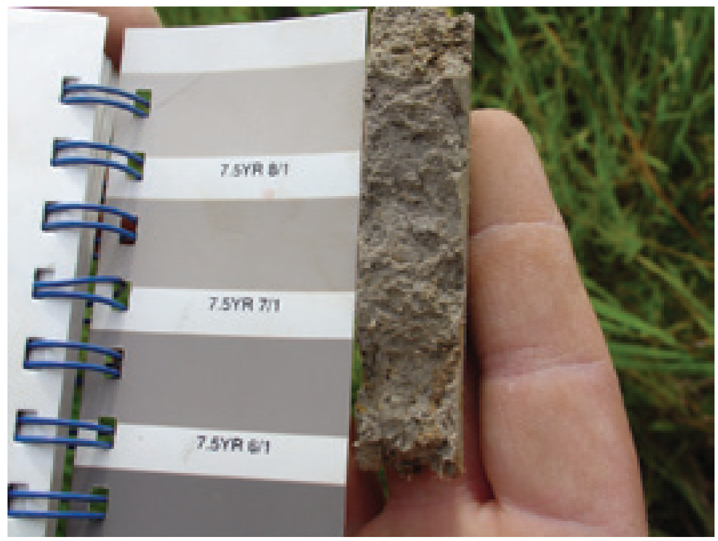

Figure 1. Munsell Color Chart used to distinguish soil color

Mineral hydric soils, such as those located on the study site (USDA, 2010) are periodically saturated for sufficient duration to produce chemical and physical soil properties associated with low oxygen. Under conditions of a fluctuating water table, mineral soils may exhibit a variety of contrasting colors within the soil profile. Low-oxygen mineral soils are usually gray and/or mottled immediately below the surface horizon, or have thick, dark-colored surface layers overlaying gray or mottled subsurface horizons. The Munsell Soil Color Charts contain pages, called gley pages, with color chips for the gray, blue and green colors often found in low-oxygen mineral soils.

While the formation of low-oxygen soils is influenced by the interactions of several soil-forming factors (climate, parent material, relief, organisms and time), the overriding factor is water. The unique characteristics of low-oxygen soils result from the periodic inundation or saturation. Prolonged soil saturation results in the displacement of oxygen within pore spaces by water. After the remaining oxygen concentration has been depleted by organisms, anaerobic conditions develop in the soil and organisms reduce other available compounds for energy.

Gleyed soils exhibit gray colors and develop when low-oxygen soil conditions result in pronounced chemical reduction of iron, manganese and other elements. Iron is one of the most abundant elements in soils. Under anaerobic conditions, iron is converted from the oxidized (ferric) state to the reduced (ferrous) state, which results in the gray colors associated with the gleying effect. Markedly reduced soil oxygen is indicated by predominantly gray soils found immediately below the A horizon or at a depth of 10 inches or less (whichever is more shallow).

Methods

The project location is in a floodplain of the South Fork of the Forked Deer River located on the West Tennessee Research and Education Center in Jackson, Tennessee. The soils in the floodplain are:

<u>Vicksburg silt loam</u> (well-drained)
    coarse-silty, mixed, active, acid, thermic typic Udifluvents
<u>Collins silt loam</u> (moderately well-drained)
    coarse-silty, mixed, active acid, thermic aquic Udifluvents
<u>Falaya silt loam</u> (somewhat poorly drained)
    coarse-silty, mixed, active, acid, thermic aeric Fluvaquents
<u>Waverly silt loam</u> (poorly drained)
    coarse-silty, mixed, active, acid, thermic fluvaquentic Endoaquepts

The predominant soils in the study location in the floodplain are Falaya and Waverly. The site has a gradual gradient in elevation that allowed blocks of seedlings to be established from higher to slightly lower elevation along the gradient.

This site was originally forested, then cleared in the 1960s, channelized, tiled and then placed into agricultural production. With marginal row crop success, the land was enrolled into the CRP and WRP.

The project was designed with solid blocks of species, each 2,680 feet long and ranging from four-to-eight rows wide (Figure 2). Seedlings were grown at the Tennessee Department of Agriculture East Tennessee Nursery in Delano, Tennessee. In the fall of 2003, the site was sub-soiled using an 18-inch, single-shank sub-soiler. Seedlings were planted during February and March 2004, using a Whitfield® Tree planter (R. A. Whitfield Manufacturing, Mableton, Georgia), which is designed specifically for planting hardwood seedlings. Trees were spaced 10' x 10' (435 trees per acre). Initial heights at planting were: water oak (18.3"), willow oak (13.1"), pin oak (14.3"), Nuttall oak (15.8"), Shumard oak (16.5"), overcup oak (20.8"), swamp chestnut oak (25.5") and swamp white oak (not available). To limit the potential effects of herbaceous vegetation on seedling responses, initial and second-year herbicide applications were applied. This consisted of Oust® XP (sulfometuron methyl, DuPont, Wilmington, Delaware) sprayed in early spring before bud break at a concentration of 1.5 oz/acre (as an 18" side-dressing).

Figure 2. Study site – solid blocks of each of the eight tree species (photo taken Feb. 2010)

In early 2010, 272 permanent plots were established within the area, 34 plots per species. Plots were located between the center rows of each block and spaced 80 feet apart (Figure 3). In March 2010, following six growing seasons, the plots were visited to record survival, height (ft.) and diameter at breast height (dbh – in.) of the four trees nearest (diagonal to) the plot center (Figures 4 and 5).

Figure 3. Measurement locations on plots were between the center rows of each block

Figure 4. Measuring tree height

Figure 5. Measuring diameter at breast height (dbh)

During June 2010, soil samples were taken at each plot and used to represent an area of 100 ft^2. The purpose was to determine the depth at which the >50 percent gray matrix occurs. At the center point of each plot, a soil probe was used to extract soil cores (Figures 6 and 7). The soil was examined in 3-inch increments to determine moist soil color and abundance or absence of gray colors. A Munsell Soil Color Chart was used to determine the hue, value and chroma of each sample (Figures 8 – 11). Colors ranged from 7.5YR 5/3 to 7.5YR 8/1. A chroma of ≤ 2 was considered a diagnostic of poorly drained conditions. The percentage of chroma ≤ 2 was recorded using a handheld data collector for each 3-inch increment. Sampling stopped at a depth where chroma 2 or less was determined to be 50 percent or greater. Depth to gray matrix was then compared with survival and growth of the oak species under study.

Figure 6. A soil probe was used to extract a soil core at each plot center

Figure 7. Extracted soil core

Using Munsell Chart to Determine Soil Drainage

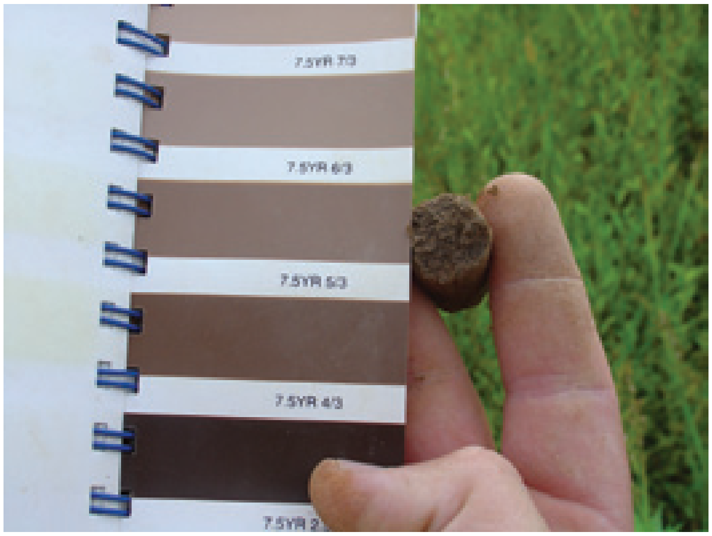

Figure 8. The soil core shown corresponds to a Hue of 7.5 YR, Value 5 and Chroma 3, which has no gray mottles.

Figure 9. The soil core shown is approximately 30 percent gray, indicating some drainage impairment.

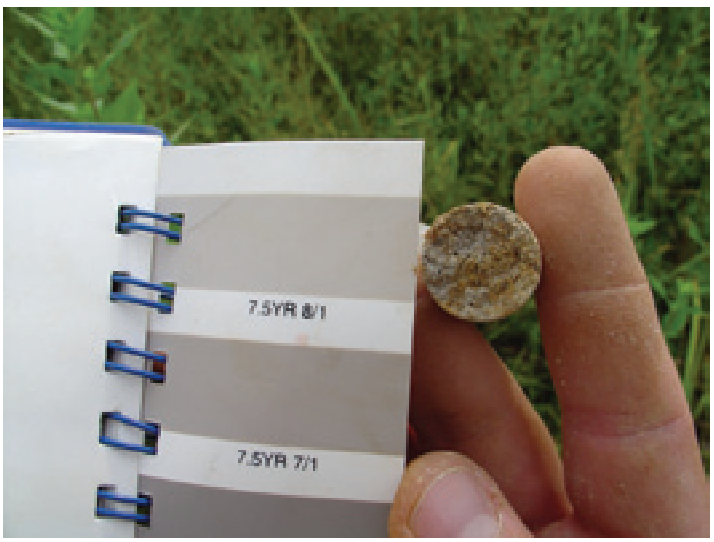

Figure 10. The soil core shown is approximately 50 percent gray, indicating poor drainage and that the gray matrix has been met.

Figure 11. These cores contrast poorly drained (left, 95 percent gray) with well-drained (right, zero percent gray) soils.

Results

<u>Soil Mottling</u>

To simplify characterizing soil conditions, soil results were placed into three broad classes. These separations were based on the depth at which the > 50 percent gray matrix occurred. Such broad classes are easier for field practitioners to observe, characterize and then match with appropriate species. The classes included:

1) <u>Poorly drained</u> – soil reached the >50 percent gray matrix within the first 0 to 9 inches,
2) <u>Somewhat poorly drained</u> – soil reached the >50 percent gray matrix at >9 to18 inches, and
3) <u>Moderately well-drained</u> – soil reached the >50 percent gray matrix at >18 inches.

In this study, of the 272 soil samples, 207 plots (76 percent) reached the > 50 percent gray matrix within the first class (0 to 9 in.), indicating the majority of the site was poorly drained. Sixty-three plots (23 percent) were within the second class (>9 to 18 in) and only two plots did not reach the >50 percent gray matrix until deeper than18 inches. Since species tolerance to the most poorly drained soils was of greatest interest, data on trees where the >50 percent gray matrix occurred within the first class (0 to 9 in.) was the class most closely examined.

<u>Survival and Growth</u>

Overall, the survival across all eight species and all soil classes was acceptable (Table 1), with a low of 74 percent (Shumard oak) and a high of 96 percent (swamp white oak). Natural resource professionals generally consider a minimum of 302 surviving hardwood trees per acre acceptable (12’ x 12’ spacing). With 435 trees per acre originally planted, even the Shumard oak (survival averaging 322 per acre) surpassed this minimum threshold.

Table 1. Survival of eight bottomland oak species in the 0- to 9-inch and the >9- to 18-inch > 50 percent gray matrix.

	Percent Survival		
Species	Across all plots	0- to 9- inch matrix	>9- to 18- inch matrix
Swamp white oak	96	96	100
Pin oak	93	93	95
Nuttall oak	90	91	84
Overcup oak	86	90	77
Water oak	88	85	94
Swamp chestnut oak	85	82	93
Willow oak	82	82	80
Shumard oak	74	70	93

Survival rate represents one diagnostic indicator of the future success of a bottomland stand. However, survival does not necessarily reflect vigor. After six growing seasons, variables such as height and dbh may be better predictors of long-term success. In order to rank the success of the eight species, both the 2010 height and dbh measurements were arranged from highest to lowest. A ranking digit (1 = best to 8 = worst) was assigned to each species for both height and dbh. The ranks for both parameters were then summed (Table 2). Species most tolerant of soil where the >50 percent gray matrix occurred within the first class (0 to 9 in.) include: Nuttall, pin and overcup oaks. Species moderately tolerant of this soil class include willow oak. Species intolerant of this soil class: water, swamp chestnut, swamp white, Shumard, cherrybark and bur oaks. The latter two species are inserted into the table, based on silvicultural information made available through the work of other scientists (Fowells, 1965; Baker and Broadfoot, 1979; Allen et al., 2001; Ozalp et al., 1997). The three divisions are based on observance of the rank sum. It was evident that rank sums less than five were most tolerant of poorly drained soils, while rank sums of 15 were least tolerant.

Table 2. Ranking of bottomland oaks in poorly drained soils where the >50 percent gray matrix is reached within 0 to 9 inches.

Species	Total height (ft.)	Ht. rank	DBH (in.)	DBH rank	Rank sum	Overall rank[1]
Nuttall oak	16.3	1	3.0	1	2	1
Pin oak	13.5	2	2.6	3	5	2
Overcup oak	13.3	3	2.8	2	5	3
Willow oak	13.3	4	2.3	4	8	4
Swamp chest. oak	10.5	5	1.9	5	10	5
Swamp white oak	9.6	6	1.9	6	12	6
Water oak	9.2	7	0.8	8	15	7
Shumard oak	8.6	8	1.7	7	15	8
Cherrybark oak[2]	-	-	-	-	-	9
Bur oak[2]	-	-	-	-	-	10

[1] When ties occurred in the rank sum, the species with the best survival where the >50 percent gray matrix is reached within 0 to 9 inches was ranked higher (Table 1).

[2] No data were collected, rankings are adapted from Fowells, 1965; Baker and Broadfoot, 1979; Allen et al., 2001; Ozalp et al., 1997.

Comparison to 18-Year-old Bottomland Red Oaks

After only six growing seasons, a clear question following this project is whether the results can be extrapolated to longer periods. Will the early champions retain their status? To examine this, trees from an earlier planting were evaluated. In 1988, a similar project adjacent to this study was established with the same bottomland red oak species (no bottomland white oaks were included) (Figure 12). The trees were planted on 9' x 9' spacing within 7 x 7 homogeneous blocks (49 trees per block). Twenty-seven soil cores were taken on this 1.5 acre area, and 100 percent of the soil cores reached >50 percent gray matrix within 0 – 9 inches. Therefore, the soil series and drainage of this second site were comparable to the study area. After 18 growing seasons, the survival, height and dbh were measured. Table 3 summarizes the results. The survival rate of Nuttall and pin oaks still exceeded 80 percent, with their height still ranking first and second. Similarly, the survival rate of Shumard, water and cherrybark oaks was 49, 45 and 34 percent respectively, all with considerably shorter height than Nuttall and pin oaks. This suggests that, at least for red oaks, the strongest early performers remain strong.

Figure 12. Adjacent stand of 18-year-old planted bottomland red oak used for comparison to 6-year-old study trees

Table 3. Summary of characteristics of six bottomland red oak species following 18 growing seasons (arranged by percent survival) on sites with >50 percent gray matrix within 0 to 9 inches.

Species	Percent survival	Average height (ft.)	Average DBH (in.)
Nuttall oak	85	55.3	7.9
Pin oak	81	55.2	6.7
Willow oak	67	54.1	7.7
Shumard oak	49	43.8	5.8
Water oak	45	52.2	7.7
Cherrybark oak	34	48.2	7.0

Discussion

The results of this work concur with the findings of others that Nuttall (Filer 1990; Ozalp et al., 1997; Stanturf et al., 1998) and overcup oaks (Stanturf et al., 1998; McCurry et al., 2010) outperform other bottomland oaks on poorly drained sites. Based on data from this study, pin oak should be added to this list, because of its tolerance to soil wetness. Although not preferred for its lumber quality, pin oak is a favorable food source for waterfowl (Allen, 2001).

Initial seedling height difference between species is not a good predictor of height at six years. Although the initial height rank of Nuttall and pin oaks were fifth and sixth, respectively, their rank had improved to first and second by year six. In contrast, swamp chestnut oak, initially the tallest seedlings, fell to fifth in rank by year six.

For most land objectives, and under normally accepted practices, species diversity is desired for bottomland restoration. Ten different bottomland oak species are present in various frequencies throughout the West Gulf Coastal Plain. Some oak species can tolerate poorly drained soils; others cannot. Species diversity is achieved most easily on soils lacking a high water table and where the soil >50 percent gray matrix exceeds 18 inches in depth. However, as the water table rises and the > 50 percent gray matrix follows it toward the surface, the diversity of oak species tolerant of such sites narrows. Table 4 summarizes species selection based on soil mottling.

Table 4. Summary of oak species selection on bottomland sites based on soil mottling and >50 percent gray matrix.

Soil drainage (classes of internal drainage)	Soil mottling (depth to >50 percent gray matrix)	Recommended oak species to plant[1]
Poorly-drained	0 – 9”	Nuttall, Pin, Overcup
Somewhat poorly-drained	>9 – 18”	Willow
Moderately well-drained	>18	Water oak, Swamp chestnut, Swamp white, Shumard oak, Cherrybark[2], Bur[2]

[1] In general, a species can be moved from a shallow mottling depth to deeper mottling depth, but not vice-versa.
[2]Adapted from Fowells, 1965; Baker and Broadfoot, 1979; Allen et al., 2001; Ozalp et al., 1997.

Conclusions

When making recommendations for the establishment of oaks (and other species) on bottomland sites, practitioners should evaluate the soil to determine at what depth the >50 percent gray matrix occurs. Because internal drainage so greatly affects tree survival and growth, the importance of matching species-to-site in bottomlands is paramount. **Practitioners should plant Nuttall, pin and overcup oaks in poorly drained soils. As the drainage improves, begin mixing in willow oak. In the best-drained soils (if they exist), finish by including water, swamp chestnut, swamp white, Shumard, cherrybark and bur oaks. Tree species diversity should expand as the soil drainage improves. The natural range of some of the species studied either ceases at or marginally extends into this physiographic region. Therefore, professionals should seek localized knowledge of the silvics of each species before incorporation into bottomland restoration regimes.**

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