COMPARISON OF SITE PREPARATION METHODS AND STOCK TYPES FOR ARTIFICIAL REGENERATION OF OAKS IN BOTTOMLANDS

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ABSTRACT.—Regenerating oak in floodplains is problematic and current silvicultural methods are not always reliable. We are evaluating the field performance of a new nursery product, the RPM™ seedling, and the benefit of soil mounding and a cover crop of redtop grass to the survival and growth of pin oak and swamp white oak regeneration on former bottomland cropfields. First-year survival was high for both RPM™ and bareroot seedlings. Basal diameter increment was significantly greater for RPM™ seedlings than bareroot stock. Although height increment was greater for RPM™ than bareroot, differences were insignificant. Neither soil mounding nor cover crop treatments significantly affected oak performance in the first year.

In Midwestern floodplains, oaks (*Quercus* sp.) and other nut (hard mast) species such as hickory and pecan (*Carya* sp.) and black walnut (*Juglans nigra* L.) were members of diverse bottomland forests containing cottonwood (*Populus deltoides* Marsh.), silver maple (*Acer saccharinum* L.), hackberry (*Celtis occidentalis* L.), sycamore (*Platanus occidentalis* L.), and black willow (*Salix nigra* Marsh.). The oaks and other nut species occurred on higher elevations that were flooded less frequently and had better-drained soils.

Oak species, including swamp white oak (*Quercus bicolor* Willd.), bur oak (*Q. macrocarpa* Michx.), and pin oak (*Q. palustris* Muenchh.), were present in the Lower Missouri and Upper Mississippi River floodplains based on the known geographic distribution and silvics of native tree species and on analyses of General Land Office surveys conducted in the early 1800s (Bragg and Tatschl 1977, Burns and Honkala 1990, Nelson 1997, Yin and others 1997, Nelson and others 1998). In Missouri, oaks were common enough to be recorded on about one-third of the survey transects of the Missouri River floodplain in the early 1800s (Bragg and Tatschl 1977). Elsewhere, oak-hickory was a recognized floodplain forest type in the Upper Mississippi River basin before European settlement. Oaks were also associates in other floodplain forest and savanna types.

Public land managers and private landowners are interested in reforesting former agricultural bottomlands with a component of native oaks and other hard mast producing tree species for:
1) improving wildlife habitat,
2) promoting native biodiversity,
3) providing recreation,
4) enhancing waterfowl hunting,
5) producing forest products, and
6) restoring ecosystem process and function.

Managers are using both natural regeneration methods and artificial regeneration techniques (tree planting and direct seeding) to meet reforestation objectives in a timely manner.

Natural regeneration is the preferred method for restoring bottomland forests because it is the least costly regeneration method. Natural regeneration of pioneer species such as cottonwood, sycamore, and willow is common following abandonment of bottomland crop fields because
1) their seed sources are widely distributed throughout the floodplain,
2) they frequently produce good seed crops,

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3) their light seeds are readily dispersed by wind and water,
4) they germinate well on mineral soil seedbeds, and
5) they have rapid initial shoot growth.

In contrast, the natural development of later successional bottomland species such as swamp white oak, bur oak, pin oak, black walnut, pecan, and shellbark hickory (*Carya laciniosa* (Michx. F.) Loud.) is more problematic due to a lack of seed source and their low regeneration potential on productive sites that are often dominated by lush herbaceous growth, woody vines, and pioneer tree species that exhibit inherently greater shoot growth. Therefore, artificial regeneration and vegetation management is typically required to reestablish species such as the oaks in floodplain environments.

However, attempts to establish oak and other hard mast producing tree species in bottomland fields using artificial regeneration methods such as direct seedling and planting of bareroot seedlings have often failed. For example, in a survey of 4-year-old Wetland Reserve Program plantings in the Mississippi River floodplain, Schweitzer and Stanturf (1997) found that only 9 percent of the total reforested land in 13 Mississippi counties met the Natural Resources Conservation Service requirement for at least 125 hard mast stems per acre in 3-year-old stands.

High rates of tree mortality and slow growth can result from
1) the use of poor quality seed or seedlings;
2) improperly planted seedlings, or sown seed;
3) damage caused by deer, rabbits, and mice;
4) drought;
5) severe competition; and
6) flooding (Stanturf and others 1998).

Loss to flooding is higher when species are planted off-site in the floodplain, i.e., their flood tolerance is not matched with the hydrologic regime of the site. Slow growing and damaged seedlings are easily overtopped by competing vegetation on these productive sites. Even when planting has been done properly, regenerating oaks in productive floodplains has proven difficult because of their slow juvenile growth habit and their adaptations to specific soil and microtopographic environments within floodplains. Further complications in regenerating oaks arise because many natural fluvial processes have been altered, changing soil, microtopographic, and hydrologic patterns.

There are a number of stock type choices and cultural methods that may improve the survival and growth of planted seedlings in bottomlands. Seedlings with larger initial diameters and more fully developed root systems have greater survival and growth rates (Kormanik and others 1995, 1998) and therefore may be more competitive on productive bottomlands. Cover crops can be planted to suppress weedy competition as well as improve seedling survival and growth (Van Sambeek and others 1986, Alley and others 1999). Soil mounding improves seedling survival and growth by raising seedlings above flood waters or high water tables, removing excess surface water, decreasing bulk density, increasing aeration, and concentrating organic matter in the root zone (Fisher and Binkley 2000).

The purpose of this study is to learn how to regenerate pin oak and swamp white oak on former agricultural bottomlands along the Lower Missouri River. We are evaluating how cultural methods such as planting trees on a soil mound and controlling competition with a cover crop can be used with different nursery seedling types to more successfully regenerate oak by improving its competitiveness in early successional bottomland communities. We are testing the field performance of a new nursery product, the RPM™ seedling whose performance will be compared with that of the more traditional 1-0 bareroot seedlings. Oak regeneration success will be related to vegetation competition, composition, and structure under the different silvicultural prescriptions. Our research focuses on solving the common problem of regenerating oaks in bottomlands and hence will contribute to our ability to reforest bottomlands with native oaks. We recognize that reestablishing oaks and other individual tree species is just one small component of restoring native bottomland forests.

METHODS

Study Area

The study is located on two conservation areas managed by the Missouri Department of Conservation: Smoky Waters (Sec. 5, T 44 N, R 9 W and Sec. 1, T 44 N, R 10 W; Cole County) and Plowboy Bend (Secs. 24 and 25, T 47 N, R 14 W; Moniteau County). Soils at the Plowboy Bend site were mapped as Sarpy Fine Sand (mixed, mesic, Typic Udipsamments). Soils at the Smoky Waters site were mapped as Haynie Silt Loam (coarse-silty, mixed, superacitve, calcarious, mesic Mollic Udifluvents) and Leta Silty

Clay (clayey over loamy, smectitic, mesic, Fluvaquentic Hapludolls). Haynie and Sarpy soils are classified as hydric, meaning that they are periodically saturated, ponded, or flooded with water during the growing season.

Plowboy Bend is protected from the Missouri River by a levee; Smoky Waters is not. The sites have not experienced flooding since the beginning of the study, although both sites were inundated during the Great Flood of 1993. Crops were previously grown in these fields until the fall of 1998. By the late summer of 1999, all study fields had a cover of herbaceous weeds and native plants.

Design

We used a split plot design for the study. We established six 40-acre fields equally divided between Smoky Waters and Plowboy Bend Conservation Areas. Each field is laid out as a square with a side being 1,320 feet in length. One of the 40-acre fields (fig. 1) at each conservation area has received no treatment after the initial site preparation, which is described below. This field represents the control and will be monitored to document natural succession that follows abandonment of bottomland cropfields. The remaining two fields at each site were designated as “management” fields and were each randomly assigned a cover crop treatment: redtop grass (*Agrostis gigantea* Roth) cover crop or no cover crop. The no cover crop field allows competing vegetation to develop naturally with the planted oak seedlings.

Within each of the two management fields, soil-mounding treatments (mounded or not) were randomly assigned across each field in groups of five rows each (fig. 2). Rows were spaced 30 feet apart and oriented parallel to the Missouri River to ensure that soil mounds would not impound surface waters. Within each group of five rows, we designated planting units to be five rows wide and 150 feet long and randomly assigned one combination of species and stock type to each of them. Each planting unit contained 30 planting sites.

Stock types included 1-0 bareroot, and two classes of RPM™ seedlings. RPM™ is a trademark for the Root Production Method, an air root pruning process developed by Forrest Keeling Nursery in Elsberry, MO (Lovelace 1998). This nursery culture technique produces a large container-grown seedling that has a dense, fibrous root system. Trees are grown in 3- or 5-gallon containers and attain heights ≥ 5 feet tall in 1 to 2 years in the nursery. In our study, RPM™ seedlings were either 1.5-year-old trees in 3-gallon pots (RPM3), or 2-year-old trees in 5-gallon pots (RPM5). Species being tested are pin oak and swamp white oak.

Seedlings were planted on a spacing of 30 feet within each row (30 x 30 foot spacing = 48 trees/ac). Within a cover crop field, mounding, stock type, and species treatments were replicated four times (fig. 3). Additional trees were planted at field edges to reforest the entire 40 acres.

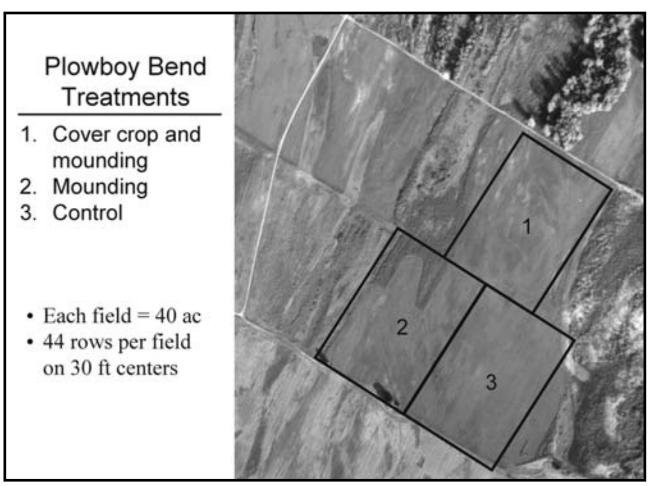

Figure 1.—*Design of study treatment fields at Plowboy Bend Conservation Area. Each field is 40 acres in area and contains 44 rows on 30-foot centers. Rows are either mounded or not. The no management field is the control where no efforts were made to direct succession.*

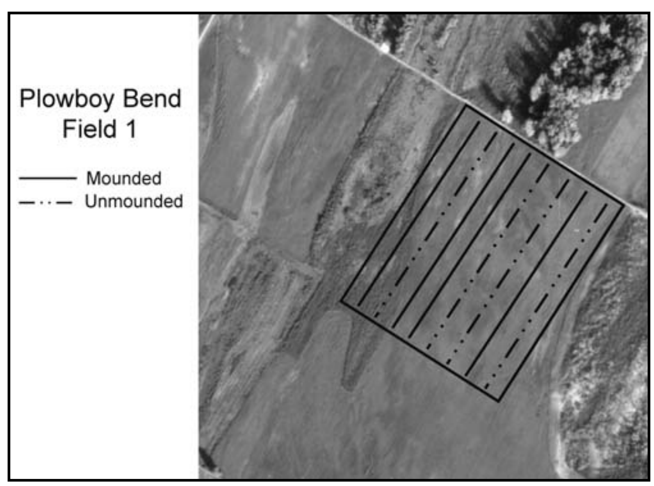

Figure 2.—*Soil mounding treatments were randomly assigned across each 40-acre management field. Each line represents 5 rows on 30-foot centers.*

Average root volumes for pin oak and swamp white oak bareroot seedlings were 1.59 in^3 and 2.03 in^3, respectively (table 1). Average root volumes for RPM3 and RPM5 pin oak seedlings were 14.44 in^3 and 13.58 in^3, respectively while those for swamp white oak RPM3 and RPM5 seedlings were 8.62 in^3 and 15.39 in^3, respectively. Root dry weight, shoot length, and shoot dry weight were also greater for RPM trees than for the bareroot stock.

Before establishing the experiment, we sampled soils to identify patterns in soil texture, hydrology, and other physical properties that may influence plot layout. Soil texture and drainage regime, as evidenced by soil morphology, were determined to a depth of 4 feet using an auger at both Plowboy Bend and Smoky Waters. We sampled soils systematically across all fields, but also sampled microtopographic features such as ridges, old side channels, and other shallow depressions. Microtopography, soil texture, and drainage did not vary substantially over the study areas and we concluded it would not affect the location or design of treatment plots.

Site Preparation and Establishment

The Plowboy Bend study site was mowed with a tractor and brush-hog in July of 1999, and gone over twice in perpendicular directions with an offset disk in August to prepare it for tree planting and sowing of the redtop grass. Site preparation at the Smoky Waters study site differed somewhat from that at Plowboy Bend because plant biomass was considerably greater. At Smoky Waters, herbicides (2,4-D and Roundup®) were applied with an agricultural

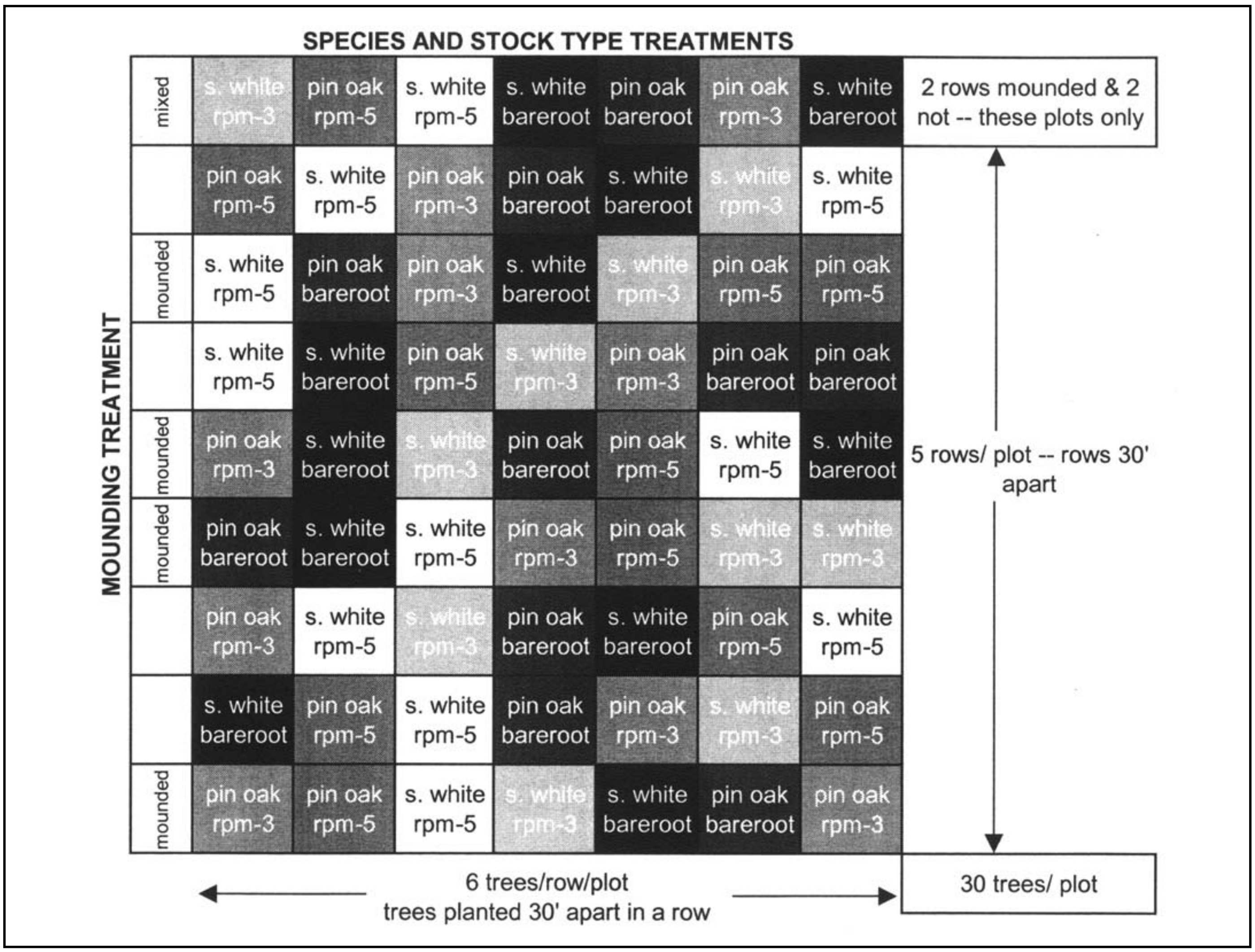

Figure 3.—L*ayout of Smoky Waters no-redtop treatment field. The various combinations of species and stock types were randomly located along the soil mounding treatment rows and were replicated 4 times within each 40-acre management field. Additional plantings were made to fill out the 40 acres. rpm-3 = RPM™ seedling in a 3-gallon container. rpm-5 = RPM™ seedling in a 5-gallon container.*

Table 1.—*Measurements of randomly selected seedlings by species and stock type at time of planting (BR = bareroot seedling; RPM3 = RPM™ seedling in a 3-gallon container; RPM5 = RPM™ seedling in a 5-gallon container). Basal diameter was measured 1 inch above the root collar (mean ± standard deviation).*

Oak species	Stock type		Basal diameter	Root volume	Root dry weight	Shoot length	Shoot dry weight
		(#)	(inches)	(in.^{3} H_2O displaced)	(grams)	(inches)	(grams)
Pin	BR	30	0.30 ± 0.05	1.59 ± 0.49	16.7 ± 5.9	27.5 ± 3.6	9.85 ± 3.3
Pin	RPM3	27	0.83 ± 0.14	14.44 ± 5.88	117.2 ± 47.8	92.5 ± 15.8	215.8 ± 83.4
Pin	RPM5	34	0.78 ± 0.15	13.58 ± 5.69	118.2 ± 42.9	91.4 ± 10.2	187.3 ± 65.2
Swamp white	BR	30	0.30 ± 0.05	2.03 ± 0.67	20.5 ± 5.98	17.9 ± 2.61	7.70 ± 2.98
Swamp white	RPM3	31	0.58 ± 0.08	8.62 ± 3.59	63.7 ± 23.5	58.2 ± 9.80	80.0 ± 31.7
Swamp white	RPM5	29	0.76 ± 0.12	15.39 ± 5.42	137.7 ± 48.5	82.8 ± 11.2	195.7 ± 69.4

Table 2.—*Initial seedling size measured by species and stock type (BR = bareroot seedling; RPM3 = RPM™ seedling in a 3-gallon container; RPM5 = RPM™ seedling in a 5-gallon container). Basal diameter was measured 1 inch above the ground surface (mean ± standard deviation).*

Oak species	Stock type	Sample size	Basal diameter	Height
		(# trees)	(inches)	(feet)
Pin	BR	1,175	0.23 ± 0.05	1.1 ± 0.2
Pin	RPM3	1,204	0.75 ± 0.13	7.2 ± 1.2
Pin	RPM5	1,269	0.79 ± 0.14	7.6 ± 1.2
Swamp white	BR	1,192	0.25 ± 0.06	1.1 ± 0.2
Swamp white	RPM3	1,274	0.66 ± 0.13	5.8 ± 1.1
Swamp white	RPM5	1,248	0.66 ± 0.13	6.1 ± 1.1

boom-type sprayer in early August. The herbicide was applied at a rate of 2.0 qt/ac of Roundup, 1.0 qt/ac of 2,4-D and 2 lbs/ac of water-soluble ammonium sulfate. Within a month, the study site at Smoky Waters was disked the same way as was done at Plowboy Bend.

In mid-September of 1999, the redtop fields were worked with an offset disk, and soil mounds were constructed with a levee plow (AMCO LF6-824) on all but the control fields. Soil mounds were about 2 feet in width at the top of the berm and 7 feet at the base. After the soil settled, mounds were about 12 inches to 15 inches in height above the natural ground elevation. In September, immediately following disking and soil mounding, redtop grass was sown at 6 lbs/ac with a two-gang roller (Brillion) seeder.

For each oak species, approximately 1,200 seedlings of each stock type were planted in randomly located 30-tree plots (fig. 3), for a total of 7,362 trees over the entire study area. RPM™ trees were planted in November of 1999 and the 1-0 bareroot seedlings were planted in the spring of 2000. Heights and basal diameters were similar between the two RPM™ stock types for each oak species. Height averaged 7.2 feet and 7.6 feet for pin oak RPM3 and RPM5 trees, respectively (table 2). Regardless of RPM™ stock type, pin oak seedlings averaged 0.8 inches in basal diameter. Swamp white oak RPM™ seedlings were slightly smaller in height and basal diameter than the pin oaks. In contrast, bareroot seedlings averaged about 1.1 feet in height and 0.2 inches in basal diameter, regardless of species.

At the time of planting, a slow release fertilizer (33-3-6 NPK) was applied to the ground surface around each seedling at an approximate rate of 2 oz. per tree. A 4 x 4 foot woven plastic weed mat was placed around each seedling in the spring of 2000.

Measurements and Analyses

Soil temperature and water were monitored at 4-inch and 12-inch depths in both mounded and non-mounded planting rows to determine if and how soil mounding affects the planted seedlings. Measurements were made in adjacent mounded and non-mounded rows at random locations within each 40-acre field. Data included in this paper are from single, randomly located installation pairs in each planted 40-acre field. Soil temperature was recorded every 3 hours with HOBO® H8 Outdoor/Industrial data loggers and permanently installed TMCx-HA temperature sensors (both from Onset Computer Corporation, Pocasset, MA).

Soil water was measured weekly with permanently installed Watermark Soil Moisture Sensors (Irrometer Company, Inc., Riverside, CA). Soil temperature data were used to adjust the Watermark Sensor meter prior to each measurement. To convert Watermark Sensor meter readings to gravimetric water content, we conducted a laboratory calibration with soil samples collected at each sensor installation and developed conversion factors for each sampling location.

To further characterize the soils at each study site, soil pits were excavated near each temperature and water sensor installation in both mounded and non-mounded locations for soil morphology description and laboratory analysis. Excavations were at least 60 inches deep. Soil horizons were identified and described and their thicknesses were recorded. Horizon description included soil color, structure and consistence, root and pore sizes and abundances, and the presence and color of redox features.

Soil samples from each soil horizon were collected for analysis at the University of Missouri Soil Characterization Laboratory including particle size distribution, extractable cations, cation exchange capacity, base saturation, organic carbon content, and pH. All soil samples were air dried and passed through a 0.08 in. sieve to obtain the fine earth fraction. Particle size distribution was determined by pipette (Gee and Bauder 1986). Cations were extracted with 1M-ammonium acetate at pH 7.0; K was determined by flame emission, and Ca and Mg by atomic absorption. Total carbon was determined by dry combustion with a Leco CR 12 Carbon Analyzer (Leco Corp., St. Joseph, MI) and pH was measured in a 1:1 solution suspension. Data from selected soil pits from each site are shown in table 3.

Initial total height and basal stem diameter 1 inch above the ground were measured on all seedlings after planting before the growing season and again at the end of the first growing season from September 2000 through April 2001.

From June through August of 2000, ground layer vegetation was monitored using randomly located paired 11-ft^2 quadrats and 33 ft x 66 ft macroplots, which were permanently marked to facilitate remeasurement. Percent ground cover by species was determined on the quadrats and macroplots. Paired quadrats, one between seedlings within a planted row and one located perpendicular to it between the rows, were used to quantify composition and abundance of competing vegetation within treatment plots. Within each 40-acre field, three replications of mounding, stock type, and species treatment combinations were sampled with paired quadrats. A total of seventy-two 11-ft^2 quadrats were installed in each field.

Three macroplots per 40-acre field were established to more thoroughly document total plant species diversity and successional patterns over time. Vertical structure of the ground flora was quantified at each quadrat location between the rows using a density board to estimate percent cover of grasses, woody vegetation, forbs, and total vegetation by 0.80-foot height increments up to a height of 6.6 feet (Hays and others 1981).

By summing the number of living stems and dividing by the total number originally planted we determined first-year survival. First-year height and diameter increments were calculated by subtracting initial measurements from the measurements made after the first growing season. We used analysis of variance (ANOVA) to determine significant ($P<0.05$) growth rate differences among species and stock type combinations between fields with and without redtop grass, and between mounded and non-mounded planting units. In this ANOVA, we used site as a random effect and tested cover crop treatment, mounding treatment, and species and stock type combinations as fixed effects with their respective site interactions as error terms. Because we found significant differences in basal diameter growth by species and stock type by site, we conducted a Duncan multiple range comparison test.

Table 3.—*Soil properties from excavations at each research site*

Location Horizon	Depth	Organic carbon	Sand	Silt	Clay	Texture class	Ca	Mg	K	CEC	pH
	in.	%	%	%	%		——————-cmol(+)kg^{-1}——————				
PLOWBOY BEND											
Ap1	0-6	0.4	84	13	3	Loamy sand	9.5	1.6	0.3	5.1	7.7
Ap2	6-10	0.4	75	20	5	Loamy sand	7.2	2.1	0.3	6.3	7.2
Cg1	10-17	0.3	51	43	6	Sandy loam	14.4	2.4	0.3	7.8	7.2
Cg2	17-3	0.4	28	63	9	Silt loam	18.4	2.0	0.3	10.3	7.5
Cg3	23-29	0.3	38	53	9	Silt loam	19.1	2.0	0.3	9.6	7.5
C1	29-43	0.1	90	8	2	Sand	11.4	1.2	0.1	3.2	7.6
C2	43-60+	0.1	94	5	1	Sand	7.6	0.8	0.1	2.6	7.7
SMOKY WATERS											
Ap1	0-5	1.3	13	56	31	Silty clay loam	28.7	4.8	1.0	24.8	8.0
Ap2	5-8	0.7	39	45	16	Loam	16.5	2.9	0.4	13.6	8.0
AB	8-13	1.1	2	67	31	Silty clay loam	19.6	4.4	0.5	25.4	8.0
Bg1	13-18	1.1	2	60	38	Silty clay loam	22.4	5.2	0.6	29.7	7.8
Bg2	18-24	1.0	2	58	40	Silty clay	21.7	6.0	0.8	29.6	7.7
Bg3	24-28	0.7	3	58	39	Silty clay loam	24.3	6.1	0.7	29.1	7.8
Cg1	28-34	0.4	1	78	21	Silt loam	22.2	4.4	0.4	18.0	7.9
Cg2	34-42	0.3	3	83	14	Silt loam	21.2	2.8	0.3	13.2	8.0
Cg3	42-49	0.3	8	79	13	Silt loam	19.8	2.4	0.3	12.0	7.9
Cg4	49-60+	0.4	28	63	9	Silt loam	20.0	2.0	0.3	11.1	8.0

RESULTS

Soil Water

Gravimetric soil water content at the 4-inch depth was greater at Smoky Waters (averaging 27 percent) than at Plowboy Bend (averaging 13 percent). At each site, soil water content was lower in the redtop field than in the no-redtop field and average differences ranged from 3 to 5 percent at Smoky Waters and 7 to 10 percent at Plowboy Bend. At the 4-inch depth, soil mounding decreased soil water content by an average of 3 percent at both Smoky Waters and Plowboy Bend (table 4). However, the effect of soil mounding on soil water content at the 12-inch depth differed by site. At Smoky Waters, soil mounding decreased soil water content by an average of 5 percent compared to 2 percent at Plowboy Bend.

Although soil water content differences between mounded and non-mounded soils were small when averaged for a growing season or an entire year, we observed that mounded soils were 10 to 25 percent drier than non-mounded soils shortly after rainfall (fig. 4). Greater soil water differences were observed at the 12-inch depth than at the 4-inch depth.

Vegetation Development

During the summer of 2000, we identified 101 plant species across all study fields at Smoky Waters and Plowboy Bend Conservation Areas. Most plants were annual and biennial forbs and grasses, of which slightly more than half were exotic species. Common native species included purslane speedwell (*Veronica peregrina* L), cut-leaf primrose (*Oenothera laciniata* Hill), and horseweed (*Conyza canadensis* L.). Many species (N=81) were not widely distributed, occurring on less than 10 percent of all the 11-ft^2 quadrats. Woody species inventoried included boxelder (*Acer negundo* L.), eastern cottonwood, hackberry, and trumpet creeper (*Campsis radicans* L.). Mean percent ground cover, in general, was greater at Smoky Waters than that at Plowboy Bend (fig. 5).

Sowing redtop grass as a cover crop increased the total percent ground cover at all sites and reduced the percent cover of other herbaceous species (fig. 5). At Smoky Waters, mean percent ground cover of other plants was reduced from about 52 percent on the no-redtop field to about 15 percent on the redtop field. Similar reductions were observed at Plowboy Bend. Species richness (mean number of species per 11 ft^2 plot) was slightly higher at Plowboy Bend than Smoky Waters.

Table 4.—*Seasonal average gravimetric water content for the two research sites at two different soil depths and by cover crop and mounding treatments*

Location and season	Soil depth	NO REDTOP Mounded	NO REDTOP Non-mounded	REDTOP Mounded	REDTOP Non-mounded
	in	% (wt/wt)	% (wt/wt)	% (wt/wt)	% (wt/wt)
PLOWBOY BEND					
Winter 2000	4	17	21	8	8
	12	18	20	11	11
Spring 2000	4	12	14	4	6
	12	10	17	3	8
Summer 2000	4	17	24	11	11
	12	22	28	31	12
Fall 2000	4	18	23	6	8
	12	16	20	7	9
Winter 2001	4	3	10	2	3
	12	11	13	4	5
Spring 2001	4	33	35	6	11
	12	9	23	2	8
Summer 2001	4	16	24	9	18
	12	10	18	2	8
Overall average	4	16	21	7	9
	12	15	20	11	9
SMOKY WATERS					
Winter 2000	4	31	29	24	30
	12	34	35	32	39
Spring 2000	4	24	27	16	21
	12	23	29	16	22
Summer 2000	4	25	27	24	28
	12	25	30	16	18
Fall 2000	4	34	35	26	30
	12	29	38	26	36
Winter 2001	4	12	31	9	11
	12	31	37	22	29
Spring 2001	4	Missing data	32	20	24
	12	26	34	17	26
Summer 2001	4	Missing data	20	32	34
	12	21	23	27	19
Overall average	4	27	28	22	27
	12	27	32	22	27

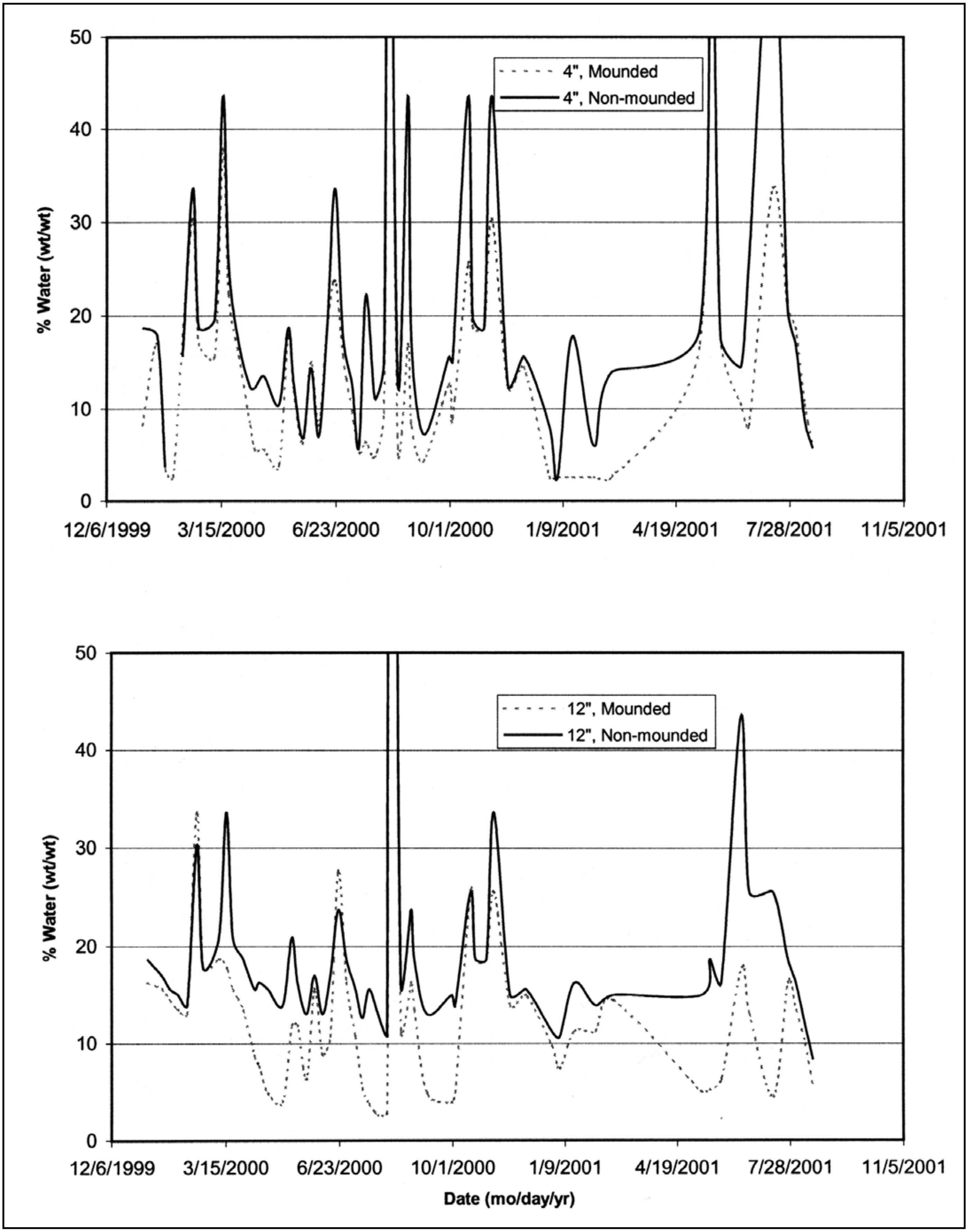

Figure 4.—*Percent soil water in mounded and non-mounded soils at 4-inch and 12-inch depth through time at Plowboy Bend Conservation Area.*

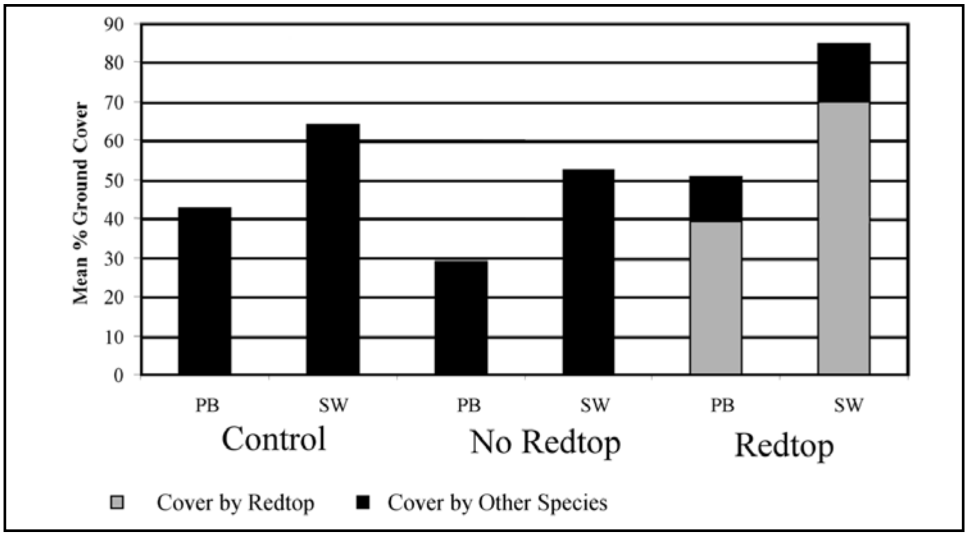

Figure 5.—*Mean percent ground cover (≤ 1.0 m above ground) by cover crop treatment at Plowboy Bend (PB) and Smoky Waters (SW) Conservation Areas.*

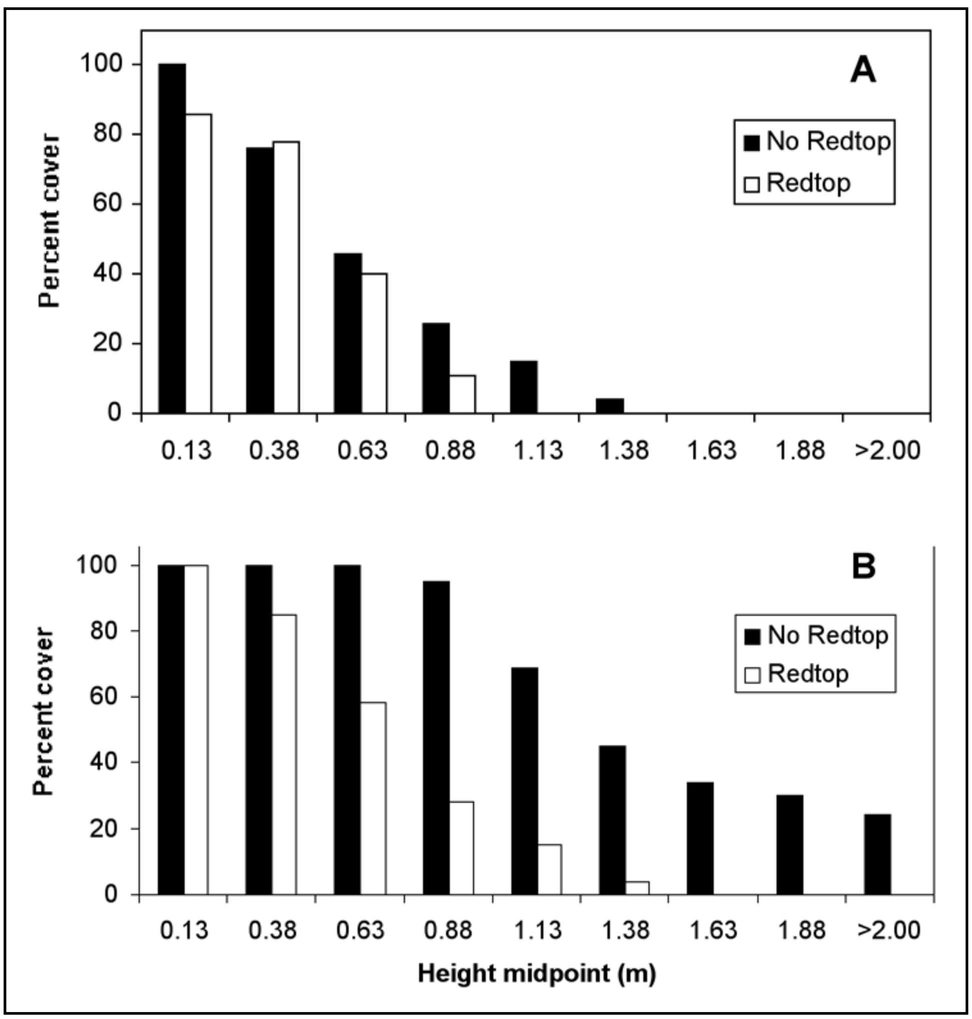

Figure 6.—*Vertical structure of ground flora at Plowboy Bend (A) and Smoky Waters (B) by cover crop treatment.*

Height and composition of the vegetation varied by cover crop treatment and between the two study sites (fig. 6). Percent cover decreased more rapidly with increasing height above the ground on the redtop grass fields than on the no-redtop fields at both Smoky Waters and Plowboy Bend. Vegetation reached greater heights at Smoky Waters than at Plowboy Bend regardless of cover crop treatment. At Plowboy Bend, vegetation grew to 4.9 feet on the no-redtop field and 3.3 feet on the redtop field. At Smoky Waters, vegetation grew to heights exceeding 6.6 feet on the no-redtop field but little vegetation was taller than 3.3 feet on the redtop field. On the no-redtop fields at Smoky Waters, total percent cover was substantial above 3.3 feet, and it averaged 24 percent above 6.6 feet. Grasses dominated (50 to 65 percent of the total percent cover) the vegetation up to 2.5 feet on the redtop fields, but they made up little of the vegetation on the no-redtop fields at both study sites.

Oak Seedling Survival and Growth

Survival was high for all species and stock types (table 5). Both RPM3 and RPM5 seedling survival was approximately 99 percent. Bareroot pin oak survival was 81 percent and bareroot swamp white oak survival was 93 percent. There was no statistical difference in seedling height growth. Bareroot seedlings showed negligible or negative height increment due to shoot dieback and resprouting, a common problem that is observed during the establishment period for hardwood bareroot seedlings (e.g., Johnson 1984). Average first-year height increment ranged from 0.3 feet for RPM3 pin oaks to 0.5 feet for RPM5 swamp white oak and pin oak seedlings.

The RPM™ seedling basal diameter growth was significantly greater ($P<0.001$) than for bareroot seedlings (table 5). Basal diameter growth of RPM™ seedlings was 0.09 to 0.16 inches, whereas bareroot growth was < 0.03 inches regardless of species (table 5). We found no significant differences in survival and growth of seedlings on mounded and non-mounded planting sites. We also found no significant differences in seedling survival and growth among fields with and without the redtop cover crop, but we recognize that this comparison lacked statistical power because of the small sample size.

DISCUSSION

Greater soil water content at Smoky Waters was caused by its finer-textured soil, which has a greater water-holding capacity than does the sandier soil at Plowboy Bend. This greater soil water content at Smoky Waters is one reason why there was greater vegetation ground cover and height than at Plowboy Bend. However, we are not certain why the redtop fields at both sites each had lower soil water contents than no-redtop fields. Although we initially suspected that the redtop grass and other vegetation in the redtop fields transpired more water than the vegetation in the no-redtop fields, we could not be certain of this because soil water content differences between redtop and no-redtop fields also occurred during the winter when vegetation was dormant. We checked our soil data to see if soil water differences could be attributed to differences in soil texture but found that soil textures at the water sensor installations did not appreciably differ from each field. However, there may be other site-specific factors causing these soil water content differences between the redtop and no-redtop fields.

Table 5.—*Summary statistics of first-year survival and growth of oaks planted in former agricultural crop fields in the Missouri River floodplain. (BR = bareroot seedling; RPM3 = RPM™ seedling in a 3-gallon container; RPM5 = RPM™ seedling in a 5-gallon container). Numbers within a column having the same superscript letter are not statistically different.*

Oak species	Stock type	Percent survival	Mean height increment (ft)	Mean basal diameter increment (in.)
Pin	BR	81	-0.1^{a}	0.01^{a}
Pin	RPM3	99	0.3^{a}	0.12^{b}
Pin	RPM5	100	0.5^{a}	0.16^{c}
Swamp white	BR	93	0.0^{a}	0.03^{d}
Swamp white	RPM3	99	0.4^{a}	0.09^{e}
Swamp white	RPM5	99	0.5^{a}	0.11^{b}

Although the soil mounding has not enhanced seedling survival or growth to date, it does appear to be decreasing soil water content. Soil water content differences between mounded and non-mounded soils were small when averaged by season or by year. However, mounded soils drained more quickly than non-mounded soils after rainfall. The full benefits of soil mounding may not become apparent until the sites experience flooding.

After 1 year, annual and biennial forbs and grasses dominated the plant community on these former bottomland crop fields. Exotic species comprised more than half of the species present during the first summer. The establishment of a cover crop of redtop grass greatly modified the development of vegetation on former bottomland crop fields after 1 year. Sowing redtop grass increased the total percent ground cover, effectively reduced the presence and vertical canopy coverage of other competing vegetation, decreased the height of competing vegetation to less than 3.3 feet, and increased the importance of grasses in the plant community. Grasses had an insignificant presence on the no-redtop fields, where competing vegetation grew to heights of 6.6 feet and higher. The vertical structure of the ground flora was more complex and well developed on the fields without redtop grass.

Total percent cover was greater with increasing heights without redtop grass, and maximum development occurred at Smoky Waters where there was still more than 20 percent total canopy cover in the 6.6 feet and above height category. Although there were substantial differences in plant community composition and structure between the cover crop treatments and between the two study sites, it is too early to conclude that the redtop grass competes less with planted oaks than does the mixture of herbaceous vegetation that develops in the absence of redtop grass. However, in the floodplains, where water is usually plentiful, light may be the limiting factor. Planting a cover of redtop grass may be a way of reducing seedling competition for sunlight. Redtop grass may also be valuable as a control of seedling damage by rodents because it reduces the escape cover available to rodents near the seedlings. This could reduce rodent populations and rodent browsing of seedlings.

The two RPM™ stock types were similar in their field performance regardless of species. Soil mounding and the use of a cover crop did not increase seedling survival or growth during the first year after planting. Survival was very high, even for the bareroot seedlings. Basal diameter growth of the RPM™ seedlings was greater than that observed in bareroot seedlings, which experienced negligible diameter growth due to shoot dieback and resprouting. Increased initial height and diameter of RPM™ trees may be enough to overcome competition present in the floodplain. Additionally, a greater diameter growth rate may further increase the chance of survival. A small proportion of the swamp white oak RPM™ seedlings produced sound acorns in the first year. Production of acorns at young ages is a common feature of oaks grown using the RPM™ method. This feature is of interest to those managing for wildlife because it shortens the time between stand initiation and the production of hard mast.

These data represent the results after 1 year. We will continue to monitor seedling survival and growth to determine if stock type, species, soil mounding, or a cover crop improves oak regeneration as the competition intensifies and the sites experience flooding. The results of this research will lead to recommended methods of oak regeneration that can be used to

1) diversify native forests that develop on abandoned cropfields by supplemental planting of oak and other nut producing trees;
2) incorporate oaks and nut trees in agroforestry operations; and
3) sustain oaks in private land forests, greentree reservoirs, conservation areas, and wildlife refuges.

Humans always have and will continue to influence floodplain environments. Our hope is that by learning about processes of hard-mast reforestation, these habitats can be managed in more productive and valuable ways.

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