ANALYSIS OF RIPARIAN AFFORESTATION METHODS IN THE MISSOURI OZARKS

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Abstract.—We evaluated the first-year survival and growth of 13 bottomland species in several different management treatments replicated at three sites in the Missouri Ozarks. Treatments were: 1) Roundup® site preparation only; and Roundup® site preparation plus a: 2) growing season application of Poast Plus® (a grass-selective herbicide); 3) redtop cover-crop; 4) ladino clover cover-crop; or a 5) Virginia wild rye cover-crop. We also compared the resulting structure and composition of competing ground flora at ground level and at 0.625 meters (average tree seedling height). Seedling survival was lowest in the Virginia wild rye treatment (83 percent) and highest in the redtop treatment (91 percent). Green ash (98 percent) and swamp white oak (97 percent) had the highest survival while eastern cottonwood (43 percent) and pecan (71 percent) had the lowest. Height growth increment by treatment was greater across all cover-crop treatments than in the herbicide-only treatments. The highest increment was redtop (9.7 cm) and the lowest was Roundup®-only (3.9 cm). Height growth by species was highest for swamp white oak (10.5 cm) and green ash (10.1 cm), whereas hackberry (-8.1 cm) and pecan (-3.9 cm) had negative growth as a result of herbivory or shoot dieback. Resulting ground flora densities were consistently lowest in the Poast Plus® treatments and highest in the Roundup®-only and rye treatments.

INTRODUCTION

In Missouri, mature hardwood forests were once abundant in floodplains of the Ozark region (Nigh and others 1992). Large-scale conversion of Ozark bottomland forests to agriculture began in the early 1800s (Jacobson and Primm 1994) and continued to be a common practice into the middle part of the 20th century. Loss of riparian forests in the Ozarks has resulted in accelerated bank erosion, channel destabilization, increases in stream temperature, and degradation of aquatic and riparian fish and wildlife habitat (Roell 1994). Overall, greater than 85 percent of the original floodplain forests in Missouri have been converted to some other use (Dey and others 2001). Currently, there is considerable interest in replanting hardwoods in old fields and former pastures along riparian corridors in Missouri, and throughout the Central Hardwood Forest Region.

Recently, a number of federal and statewide efforts to re-establish bottomland hardwoods have largely met with poor or mixed success (Dey and others 2001, Kabrick and Dey 2001, Stanturf and others 2001, Dugger and others 2004, Kabrick and others 2007). Initial stages of such restoration projects are important and will subsequently direct successful hardwood establishment. Important considerations include: species appropriateness to site, seedling stock type, wildlife damage, tree planting technique, and groundcover management. Overall, methods for restoring bottomland hardwoods have not yet been fully developed.

Most riparian afforestation projects have focused on planting hard-mast-producing species, such as oaks (*Quercus* spp. L.), pecan (*Carya illinoinensis* (Wangenh.) K. Koch), and black walnut (*Juglans nigra* L.). Less

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commercially valuable light-seeded species are often omitted, in part because of the assumption that these species will naturally establish themselves. However, Stanturf and others (2000) suggested that relying on the natural establishment of light-seeded, wind-dispersed species into agricultural forest conversions may be impractical or unsuccessful. Consequently, interest is increasing in including these species in bottomland plantings (Lockhart and others, in review). However, there is little information about the artificial regeneration of many of the light-seeded species.

Vegetation management is an extremely important part of any afforestation project, and only second to species-site considerations (Van Sambeek and Garrett 2004). Groundcover management can be used to reduce competition for water and nutrients and to minimize labor and equipment costs. To gain the greatest positive effects on plantation success, vegetation management should be conducted during the first 1 to 3 years following planting (Miller 1993). Types of management include mechanical or chemical control of competing vegetation, and planting cover-crops. Mechanical control includes mowing, which is a common practice managers use to facilitate chemical treatments, and to help locate newly planted trees. However, mowing itself is ineffective for controlling competing vegetation for improved seedling survival and growth (Van Sambeek and Garrett 2004). Chemical methods include application of a variety of pre- and post-emergent herbicides, including those that can be applied over trees, such as grass-selective herbicides. Cover-crops have also been shown to be effective in suppressing competing vegetation, leading to improved tree survival and growth (Van Sambeek and Garrett 2004). In addition, cover-crops may be used to conserve soil and to improve water quality (Dey and others, in review). Specifically, grass species such as redtop (*Agrostis giantea* Roth) have been successfully established in bottomland hardwood plantings in Missouri with a minimal investment, high success, and little follow-up management (Dey and others 2003). Other options for cover-crops include legumes with nitrogen-fixing properties, such as clovers (*Trifolium* spp. L.). Legumes have often proven more successful in hardwood tree plantings than both grasses and resident vegetation (Van Sambeek and Garrett 2004). To date, there has been little research in using native species for this type of work. Many have speculated that Virginia wild rye (*Elymus virginicus* L.) might be a suitable option because of its general distribution and growth habit. In Missouri, Virginia wild rye grows in a variety of settings, from intact riparian communities, to glades and old fields (Yatskievych 1999).

OBJECTIVES

Our objective was to compare the effect of two herbicides and three cover-crop management practices on 13 species of seedlings to identify successful afforestation methods for use in riparian ecosystems of the Ozark Highlands.

STUDY AREAS

Three replicate sites were included in this study. Study locations were selected based upon their geographic distribution, placement within watershed, current and former land condition, and land ownership type. All sites were located within the Ozark Highlands Ecological Section, as described by Nigh and Shroeder (2002) (Fig. 1). Study areas were confined to this region because of the distinctive topographical characteristics and area-specific land management questions occurring here. Waterways within this region flow through a highly dissected, unglaciated landscape. Streams adjacent to Ozark riparia are mostly spring-fed and carry little suspended sediment (Nigh and Schroeder 2002). Here, drainage systems are characterized as “open,” with a brief water residence time. Compared to surrounding regions, fluvial soils are coarsely grained and droughty. Stream systems of this study were 2nd and 4th order (Strahler 1957). Each research plot was located on well developed and relatively stable point-bar floodplains subject to

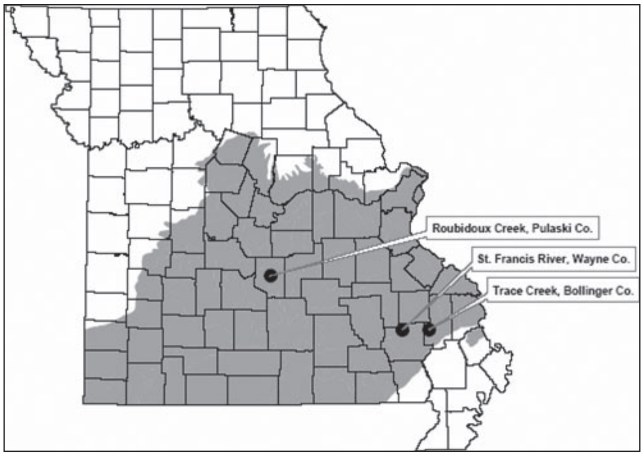

Figure 1.—Study site locations in Missouri. Ozark Ecological Section is shaded in gray (Nigh and Schroeder 2002).

Table 1.—Soils and associated physical characteristics of each study site

Study site	Soil series	Landform type	Drainage class	Taxonomic class
St. Francis River	Bucklick	footslope	well	Fine, mixed, active, mesic Typic Hapludalfs
	Crider	footslope	well	Fine-silty, mixed, active, mesic Typic Paleudalfs
	Fourche	terrace	moderately well	Fine-silty, mixed, active, mesic Glossaquic Paleudalfs
	Freeburg	terrace	somewhat poorly	Fine-silty, mixed, superactive, mesic Aquic Hapludalfs
	Raccoon	terrace	poorly	Fine-silty, mixed, superactive, mesic Typic Endoaqualfs
	Secesh	terrace	moderately well	Fine-loamy, siliceous, active, mesic Ultic Hapludalfs
Trace Creek	Razort	floodplain	well	Fine or coarse-loamy, mixed, active, mesic Mollic Hapludalfs
	Secesh	floodplain	well	Fine-loamy, siliceous, active, mesic Ultic Hapludalfs
	Tilk	floodplain	well	Loamy-skeletal, siliceous, active, mesic Ultic Hapludalfs
Roubidoux Creek	Kickapoo	floodplain	well	Coarse-loamy, mixed, superactive, nonacid, mesic Typic Udifluvents
	Sandbur	floodplain	somewhat excessively	Coarse-loamy, siliceous, superactive, nonacid, mesic Mollic Udifluvents
	Relfe	floodplain	excessively	Sandy-skeletal, siliceous, mesic Mollic Udifluvents

occasional to infrequent flooding. Prior to site establishment, Missouri Department of Natural Resources soil scientists mapped the soils at each site at a resolution of 1:2,000 (Table 1). Sites were generally located on floodplain or terrace landforms. Soil orders were either Entisols or Alfisols and ranged from excessively well drained with sandy-skeletal texture, to somewhat poorly drained with fine-silty texture. Planting area at each site ranged from 1.5 to 2 hectares in size.

Table 2.—Species, number of seedlings, and mean initial height of bare-root seedlings (or cuttings of cottonwood) used in this study. Initial measurements were not collected for eastern cottonwood. Fisher's least significant difference = 2 cm.

Common name	Latin name	n	Initial height (cm)
Swamp white oak	*Quercus bicolor*	212	34
Northern red oak	*Q. rubra*	374	47
Pin oak	*Q. palustris*	204	48
Shumard oak	*Q. shumardii*	373	49
Bur oak	*Q. macrocarpa*	378	43
White oak	*Q. alba*	367	35
Black walnut	*Juglans nigra*	430	45
Pecan	*Carya illinoinensis*	367	39
White ash	*Fraxinus americana*	363	55
Green ash	*F. pennsylvanica*	383	55
American sycamore	*Platanus occidentalis*	375	78
Hackberry	*Celtis occidentalis*	364	51
Eastern cottonwood	*Populus deltoides*	311	--

METHODS

We evaluated first-year growth and survival response of 13 native tree species commonly used in bottomland plantings in the Ozark region (Table 2). Bare-root seedling stocks were used, which are the most widely-available and commonly used stock type in the region (Dey and others, in review). All seedlings were planted in March or April of 2006. Seedlings were purchased from the George O. White State Tree Nursery near Licking, MO. All seedlings were either 1-0 or 2-0 stock, with the exception of eastern cottonwood (*Populus deltoides* Batr. ex Marsh.), which were planted as 30-cm cuttings. Prior to planting, seedlings of all species were randomly packaged together to ensure random placement in the field.

All planting locations were initially sprayed with a 2 percent solution of Roundup® (41 percent a.i.) to eliminate pre-existing cool-season pasture grasses and other agricultural weeds. Treatments were: 1) Roundup® site preparation only; and Roundup® site preparation plus a 2) single growing season application of a grass-selective post-emergent herbicide, Poast Plus® (13 percent sethoxydim a.i.); 3) redtop cover-crop; 4) ladino clover (*Trifolium repens* var. *giganteum* L.) cover-crop with annual wheat (*Triticum aestivum* L.) nurse-crop; and 5) Virginia wild rye cover-crop with a Korean lespedeza (*Kummerowia stipulacea* [Maxim.] Makino) nurse-crop. Following the initial Roundup® application, fields receiving the three cover-crop treatments (i.e., redtop, clover, and rye treatments) were disked to a depth of 3 inches. Seed was then broadcast with either a hand-spreader or a PTO-powered tractor-mounted seeder directly before tree planting in March or April. Each treatment was planted separately at the following seed mixtures and rates: redtop at 11.1 kg per ha, ladino clover at 4.5 kg per ha, annual wheat at 174 L per ha, Virginia wild rye at 17.8 kg per ha, and Korean lespedeza at 8.9 kg per ha. Following seeding, a section of chain-link fence was dragged behind an all-terrain vehicle to maximize seed-soil contact. The "Poast Plus®" treatment was left idle until the target grass species were actively growing. The "Roundup®-only" treatment areas were left idle for the remainder of the study.

Following cover-crop seeding, tree seedlings were planted during the same day using a tree planter. A minimum of 20 seedlings per species per treatment were planted (Table 2), for a total of 4,501 seedlings. Planting spacing was somewhat dependent upon site area, but was generally 3 m x 3 m. A work crew followed the tree planter and replanted any poorly planted trees as needed. Following planting, initial height and diameter data were collected. All seedlings were remeasured in November 2006 at the completion of the first growing season.

Ground flora was surveyed during peak vegetative productivity of the growing season (i.e., middle July - early August) to quantify competing plant composition, abundance, and structure within each site and treatment type. Eighty 1-m^2 sample quadrates per hectare were randomly assigned to each treatment. Quadrats were aligned prior to field entry using geographic information systems software with aerial photographs and the previously collected soils data. At each quadrat, percent cover by species was tallied for any species comprising a minimum of 1 percent of the quadrat area, and all data recorded to the nearest percent. Each species was tallied regardless of its vertical placement within the quadrat. Therefore, it was possible that with vertical layering of vegetation, the sum of all species together could equal more than 100 percent. These data were used to quantify the vegetation competing for below-ground resources (e.g., water, nutrients, rooting space). In addition to quadrat (i.e., ground-level) data, information was recorded for foliar density by height class using a 2.5-m-tall by 0.3-m-wide profile board, with alternating black and white painted bands at each 0.25-m interval (Nudds 1977). These data were collected at 40 plots per hectare. At each plot, the profile board was oriented along the outside edge of the 1-m^2 quadrate frames used for the ground level sampling. Based on a specified azimuth, a logger's tape was used to establish a sampling point at a distance of 15 m. The amount of vegetation obscuring each 0.25-m interval on the profile board was estimated to the nearest percent for each plot. Observers ensured that their line-of-sight coincided directly with the height interval being measured.

We compared seedling survival and growth using analysis of variance (ANOVA) in a split-plot design, with the five groundcover treatments as the whole-plots, and the 13 species within treatments as the split-plots. The error term used was site (i.e., block) and was considered a random effect. Ground flora data (i.e., ground-level and foliar density by height class) were analyzed as an ANOVA randomized complete block design with percent cover as the response variable. Each site was one block. For significant effects (α = 0.05), we used the Fisher's least significant difference using the least squares means for all mean separations.

RESULTS

Seedling survival was more than 87 percent for all treatments. However, there were differences among treatments ($p = 0.03$, Fig. 2). Seedling survival in the rye cover-crop (83 percent) was lower than seedling survival for both redtop cover-crop (91 percent) and Poast Plus® (89 percent). The Roundup®-only treatment and clover cover-crop were in the middle.

Survival differed significantly among species ($p < 0.01$, Fig. 2). Green ash survival exceeded 98 percent, surpassing pecan, sycamore, and cottonwood, which had the lowest survival. White oak and pin oak survival was approximately 90 percent. White ash, hackberry, black walnut, swamp white oak, northern red oak, Shumard oak, and bur oak all exhibited similar survival rates, between 94 and 96 percent.

Vegetation management treatment significantly influenced seedling height growth increment ($p < 0.01$, Fig. 3). Seedlings grown in a cover-crop of either redtop, clover, or rye performed better than those grown

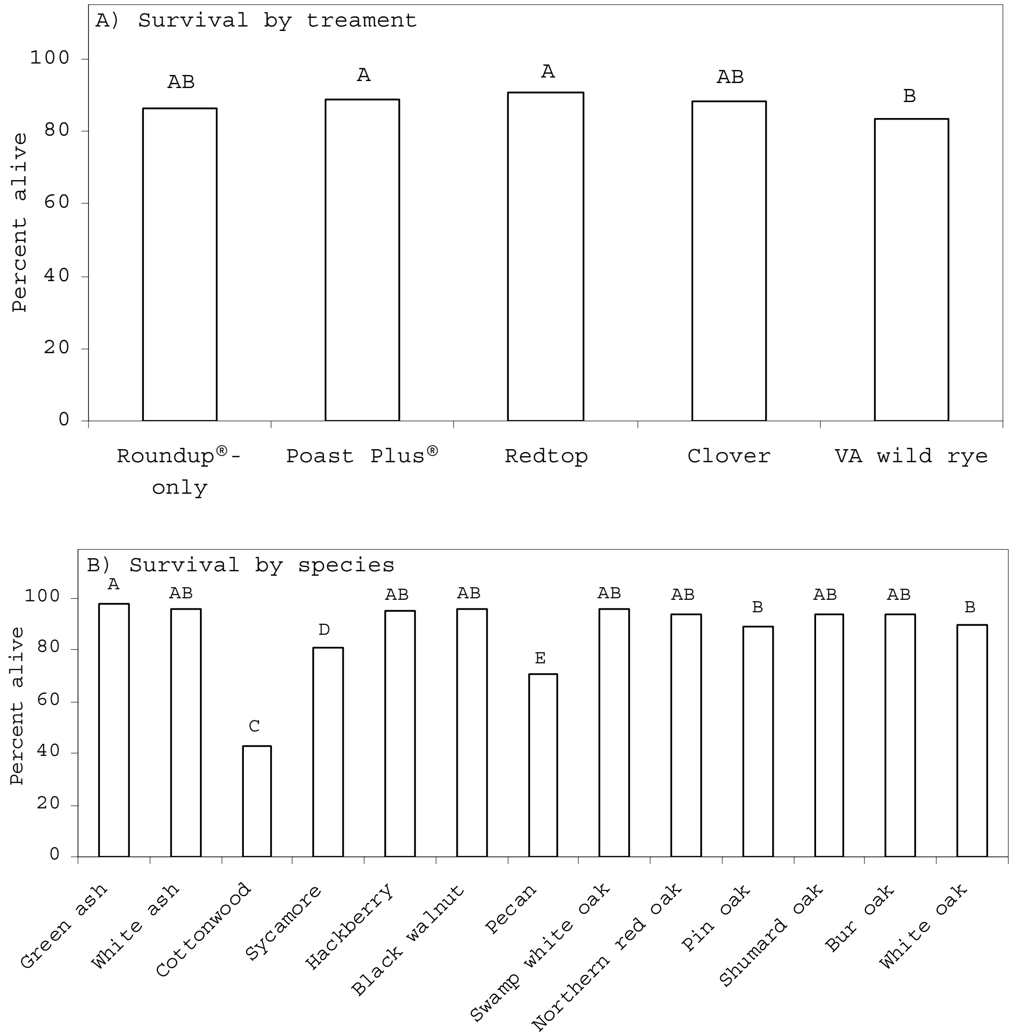

Figure 2.—Mean survival by (A) treatment (all species) and (B) species (all treatments). Letters above bars indicate statistical significance using Fisher's least significant difference for mean separations (α = 0.05).

with Roundup® only. Seedling growth increment in the Poast Plus® treatment was not significantly different from the Roundup®-only treatment. Overall, redtop nominally had the highest average growth of 9.7 cm, while the Roundup®-only treatment had the lowest, at 3.9 cm.

Height growth varied greatly among species ($p < 0.01$, Fig. 3). Eastern cottonwood had the highest average growth at 49.1 cm, which was much greater than all other species. Height growth of green ash and swamp white oak was greater than sycamore, hackberry, black walnut, pecan, Shumard oak, and bur oak. Hackberry and pecan each had negative growth, resulting from herbivory or shoot dieback. White ash, northern red oak, pin oak, and white oak all had similar height growth patterns, and were lower than green ash and swamp white oak.

The treatment effects for ground flora densities in both the foliar density by height class and ground level were highly significant ($p < 0.01$, Fig. 4). For foliar density by height class, we included only the 0.625-m interval, since this represented the average height of seedling foliage and the level at which a seedling's ability to capture light for production of photosynthate could be inhibited. For treatment effects of ground

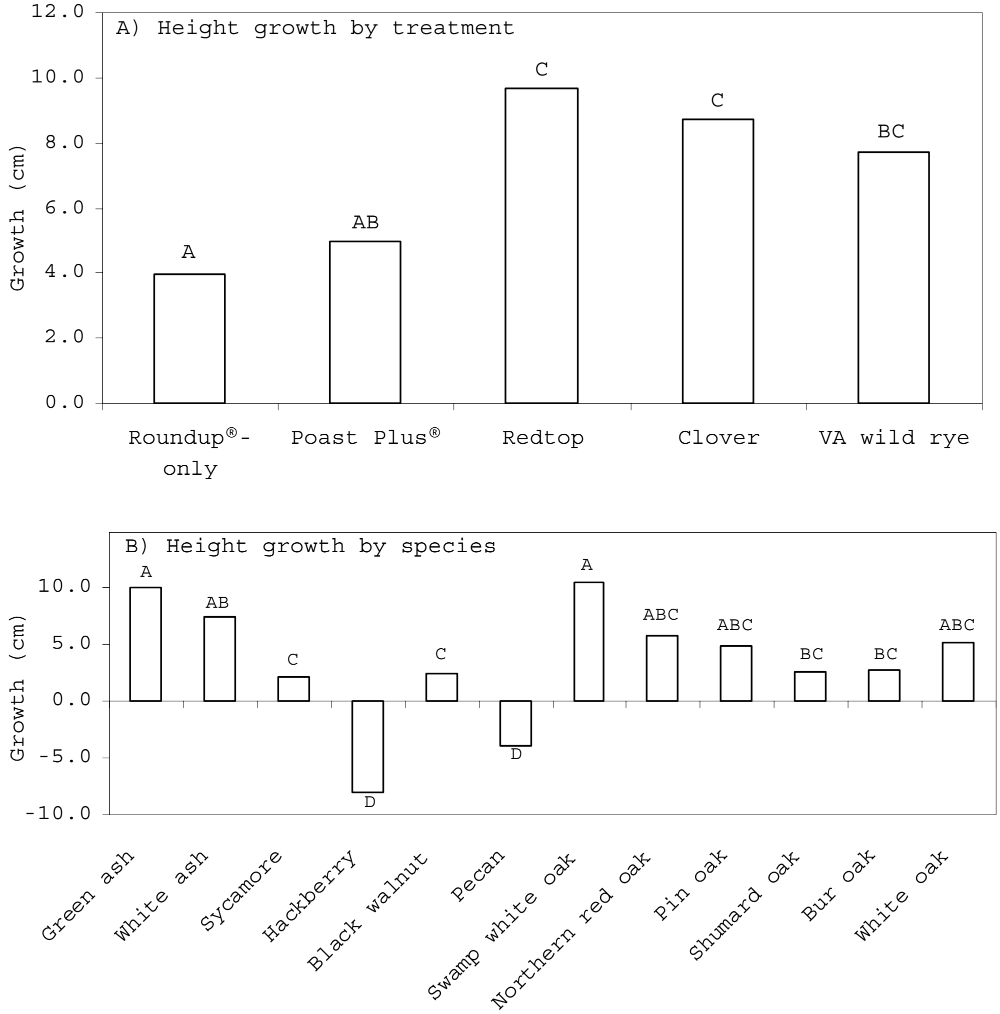

Figure 3.—Mean height growth by (A) treatment (all species) and (B) species (all treatments). Average height growth of cottonwood was 49.1 cm, and was omitted in order to key in on other species. Letters above bars indicate statistical significance using Fisher's least significant difference for mean separations (α = 0.05).

flora density at 0.625 m, Poast Plus® was significantly lower than all other treatments (49 percent). Foliar densities for the other treatments were similar, ranging between 84 and 95 percent. At the ground level, the highest density was in the rye cover-crop (exceeding 100 percent), for greater than both Poast Plus® and clover, each of which were lower than 75 percent. Roundup®-only and redtop fell in the middle, both having above 90-percent cover.

DISCUSSION

In Missouri, it is common for first-year seedling survival rates to be high. However, our study showed significant seedling survival differences among treatments. Rye had lower seedling survival than redtop and Poast Plus® at the end of the first growing season (Fig. 2) probably related to unsuccessful rye establishment. Although it was planted at a high seeding rate, the rye was nearly absent on all sites, leading to elevated competing ground flora densities (Fig. 4). During data collection, crews were instructed to specifically look for rye germinants, but few were found. This could have been a result of planting methodology, poor seed quality, or inadequate seed source. In addition, many native grasses can often take two to several years to establish (Launchbaugh 1976), which may be the case here. For surviving

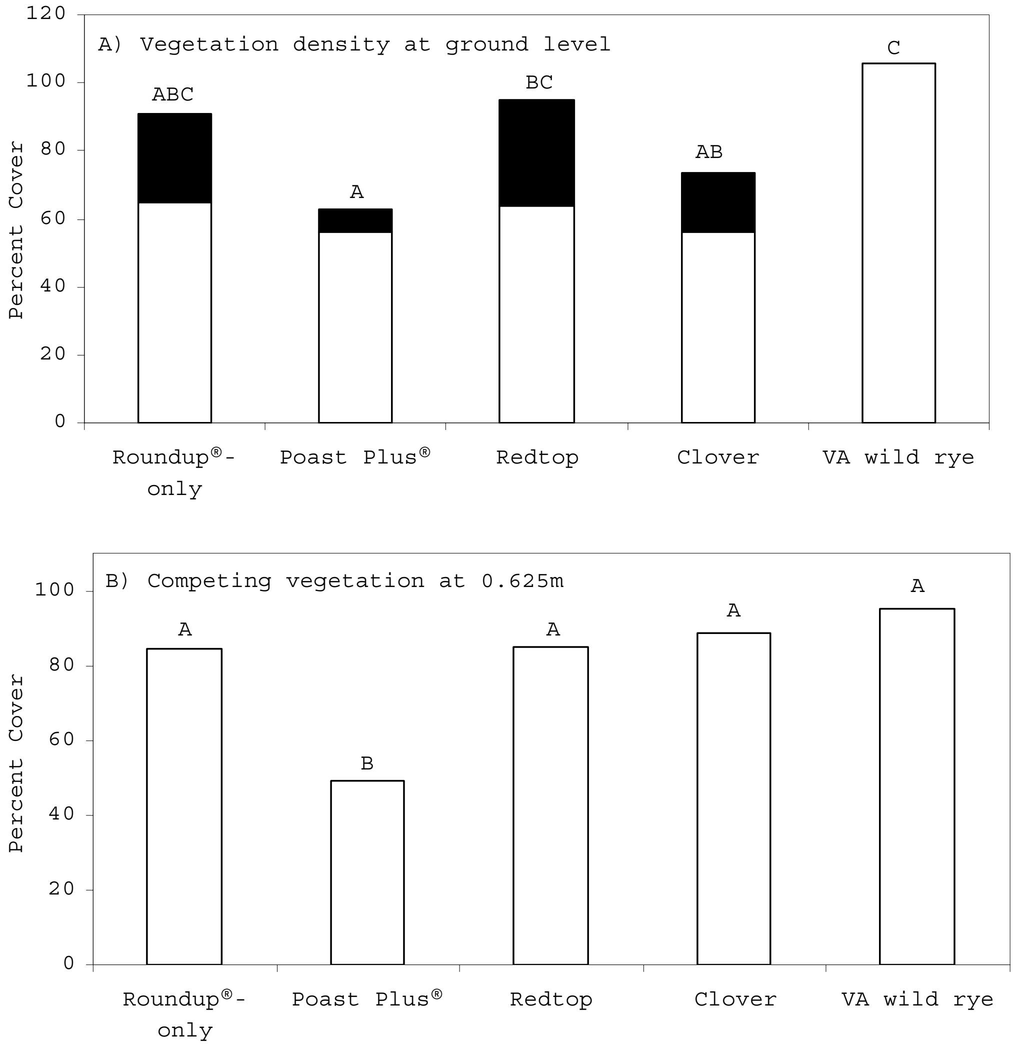

Figure 4.-Mean ground flora density by treatment. In graph A, filled portion of the bar indicates the proportion of the cover-crop relative to other species and the proportion of grasses in the Roundup(r)-only and Poast Plus(r) treatments. Graph B shows the cover of all species at 0.6 m above ground, the average height of seedling foliage. Letters above bars indicate statistical significance using Fisher's least significant difference for mean separations (α = 0.05).

tree seedlings, height growth was greater in the cover-crops compared to the herbicide-only treatments. Even in the rye treatment, which had the lowest survival, the remaining live seedlings grew more than the herbicide-only treatments. This result may be attributable to disking that occurred in the rye treatment plots. Disking seemed to provide a good planting medium, which may lead to a more effective capture of adequate moisture and nutrients for seedlings. Disking also slows the initial growth of resident vegetation early in the growing season, during the time many seedlings are developing their first flush.

For most species, seedling survival exceeded 90 percent and only cottonwood, sycamore, and pecan exhibited low survival (Fig. 2). Height growth, however, varied substantially among species. Green ash and white ash provided the best height growth for the light-seeded species, and both had 96-percent survival (Fig. 3). Eastern cottonwood had low survival, but surviving cuttings grew nearly 0.5 m. One reason for the variable results of cottonwood is that they were planted as cuttings, which often have lower survival (Kabrick and others 2007). In addition, it was found later that a number of these cuttings were planted with the lateral buds facing down, which likely caused reductions in survival and growth. For the hard-mast-producing species, swamp white oak had the best survival and growth, with averages that often surpassed that of green ash. Northern red oak and white oak also had higher survival and growth. For each species, height growth was greater than 5.0 cm.

At all sites, the annual nurse-crops (i.e., annual wheat and Korean lespedeza) for the clover and rye treatments were established with success, which helped reduce density of early volunteer vegetation in these treatments. In most cases (except for the rye treatment), the perennial cover-crops were successfully established. The ladino clover germinated uniformly at all sites and was 18 percent of the total vegetation density at time of sampling. During this time, the clover was probably past its peak growth while other vegetation was maturing, which may have resulted in lower numbers than if the data had been collected earlier in the growing season. The redtop established well at two of the three sites, and totaled 31 percent vs. 56 percent resident vegetation (at ground level). In terms of area covered by competing plant material, the Poast Plus® and redtop seem to be the most effective means of vegetation management.

Restoration Implications

Planting hardwood seedlings in drought-prone regions like the Missouri Ozarks can be difficult. Soil conditions even in floodplains can be water-limiting for extensive periods of time. Competition from aggressive, early-successional vegetation, and occasional seasonal flooding can make the task even more cumbersome. It is likely that the species and treatment results we reported will change in coming years. However, initial stages of this type of restoration effort can have important long-term consequences for the growth and development of riparian forests. Species like swamp white oak and green ash each exhibited high survival and growth under these difficult conditions. In addition to being good competitors in a weedy and dry environment, swamp white oak and green ash seedlings are well adapted to the seasonal flooding that will inevitably occur in the future (Burns and Honkala 1999, Kabrick and others 2007). Management treatments such as planting redtop or clover cover-crops and conducting timely follow-up herbicide applications of Poast Plus® may result in a less dense and less-competitive ground flora layer. Annual follow-up management and selecting a variety of bottomland species native to your region are suggested to ensure successful establishment of a riparian afforestation project.

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