LONGER BLACK WILLOW CUTTINGS RESULT IN BETTER INITITAL HEIGHT AND DIAMETER GROWTH IN BIOMASS PLANTATIONS

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ABSTRACT

Black willow (*Salix nigra* Marsh.) has the potential to be a viable plantation species for biomass production on heavy clay soils throughout the southern United States. The most favorable planting stock for woody biomass plantations is dormant unrooted cuttings, because they are easy to plant and use of clonal material allows for advancing genetic improvement. The purpose of this study was to determine the optimal cutting size and planting depth for maximum survival and growth of unrooted black willow cuttings. A test using three cutting lengths (9, 15, 21 inches), four cutting diameters (⅜, ½, ¾, 1 inches), and three planting depths that left 2, 5, and 8 inches of exposed unrooted cuttings was established in 2009, and survival and growth were measured for two growing seasons. Second-year survival exceeded 99 percent across all treatment combinations and was not influenced by any of the experimental factors. Total height differed among cutting length and cutting diameter. The 21 inch cuttings produced stems with the greatest heights and diameters two growing seasons after planting, but the largest cutting diameters did not produce the same effect. Our results indicate that cutting length had a stronger influence than either cutting diameter or planting depth on black willow height and diameter growth during the first two growing seasons after planting.

INTRODUCTION

Short rotation woody crops (SRWCs) are characterized by fast growing tree species, grown in plantation culture under a greatly reduced timeframe for either pulp or biomass production. This type of plantation system has attained significant acreage in Europe, and will become increasingly important in the United States as renewable energy demands turn to woody biomass as a source of biofuel feedstock. Black willow (*Salix nigra* Marsh.), a species native to North America, possesses a range of silvical qualities that demonstrate high potential for culture in SRWC plantations. These characteristics include extremely fast growth, ease of vegetative reproduction via stem cuttings, and ability to grow on extremely wet sites not typically favorable to other SRWC species. In spite of its extraordinary biomass production potential for biofuel feedstock, there is little information to support black willow establishment and management techniques in a plantation setting.

Black willow is among other SRWC species, e.g. cottonwood (*Populus* spp.) and sycamore (*Platanus* sp.), naturally found on alluvial sites (Morgenson 1992). However, black willow is more flood tolerant than these other species and grows on soils that are at best only marginal for row crop production as well as other commercially viable tree species.

Considerable work on willow biomass production has been conducted in the northeastern United States using a number of shrub willow species (Abrahamson et al. 2002). The same research effort has not extended into the southern region of the country where black willow is the predominant willow species. Research from the northeast indicates vegetative propagation with unrooted cuttings is the most economical and efficient method of establishing willow plantations (Abrahamson et al. 2002). Additionally, work on poplar, a closely related genus, indicates larger cuttings exhibit best survival and growth, and cuttings harvested distally from the terminal showed best rooting (Morgenson 1992). Dickmann (1992) noted that cutting diameter influenced poplar survival and growth.

Research on black willow is needed in the southeast region of the United States to support development of its potential as a viable biomass feedstock species. Plantation establishment using unrooted cuttings must be understood to optimize survival and growth in production settings. The purpose of this study was to determine the optimal cutting size and planting depth of unrooted black willow cuttings for maximizing survival and growth. Results from this research are expected to aide future studies and allow more focused research on other aspects of black willow silviculture. In addition, this study will provide landowners with knowledge of planting stock requirements for establishing dedicated bioenergy plantations using black willow.

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MATERIALS AND METHODS

The study was established in March 2009 at the Mississippi Agricultural and Forestry Experiment Station in Stoneville, MS. The site was a former agricultural field in the Lower Mississippi Alluvial Valley (LMAV), with soils in the Bosket and Commerce series. The Bosket series are fine sandy loams and the Commerce series are silty clay loams; both are poorly drained with a water table depth of around 20 inches and less than 2 percent slope. Annual rainfall for the site averages 55 inches with a long growing season.

Dormant black willow whips were collected from a single geographic source, which included a small area in southwest Oktibbeha County, MS. The whips were harvested, in December 2008, from only one geographic source to minimize genetic variation and allow for full expression of treatment effects. Whips were cut to the appropriate length, grouped into the appropriate sizes, and stored at 34 °F until planted. The planting site was prepared by disking and sub-soiling to a depth of 16 inches on 10 foot centers to break any possible pans. Cuttings were hand planted at 6 x 10 ft spacing. A broadcast application of Goal 2XL (oxyfluorfen), at 48 ounces to the acre, was used prior to black willow bud break to reduce herbaceous competition early in the first growing season. Mechanical practices controlled competing vegetation during the remainder of the first growing season. Canopy closure reduced competing vegetation during the second growing season minimizing the need for mechanical weed control. No silvicultural applications were conducted in the second growing season.

The experiment was established as an incomplete 3 x 4 x 3 factorial according to a randomized block design. There were 3 levels of cutting length (9, 15, 21 inches), 4 levels of cutting diameter (⅜, ½, ¾, and 1 inch), and 3 levels of planting depth that left 2, 5, and 8 inches of exposed cutting. There was an incomplete set of 32 treatment combinations, because the combination of the 9 inch cutting with 8 inches of exposed cutting was not practical. Thus, the four treatment combinations of 9 inch cuttings, planted 1 inch deep, for each of the 4 different cutting diameters were omitted from the experiment. All treatment combinations were assigned in plots of 4 cuttings, and plots were replicated in each of 4 blocks. A total of 512 cuttings were planted for this study, plots were surrounded by two buffer rows of planted cuttings. All sample stems were measured in December 2009 and 2010. Measurements included height to the nearest tenth of a foot and diameter, one foot above the cutting, to the nearest hundredth of an inch. Statistical analyses tested for treatment effects on height and diameter by plot means basis at an alpha level of 0.05. Means from significant effects were separated with Fisher’s LSD in tables 1, 2, and 3.

RESULTS

The objective of this study was to determine the optimal cutting length, cutting diameter, and planting depth for maximizing survival and growth of black willow unrooted cuttings. Survival, height, and diameter were measured for two consecutive years in this experiment. For all treatments, shoot height averaged 8.9 feet for the first year and 15.9 feet for the second. Mean shoot diameters were approximately 1 inch for the first year and 1.79 inches for the second. Survival was high across the study and did not differ by treatment. Only two trees died in the first year and none in the second, resulting in a survival percentage of 99.6 percent in both years. Results indicate the longest cuttings exhibited the most vigorous shoot height and diameter growth (Table 1). On average, 21 in. cuttings developed shoots almost 4 percent taller and 7.5 percent larger in diameter than 9 in. cuttings. Cutting diameter also influenced height and diameter growth of shoots, but growth trends relative to this factor did not follow any logical sequence (Table 2). The smallest diameter cutting (3/8 inches) produced the greatest height and diameter growth for both years, but was not followed by the next level of cutting diameter (1/2 inches). Two years after plantation establishment, planting depth had little impact on black willow shoot growth (Table 3).Shoot height was did not differ among planting depths, while shoot diameter increased about 3 percent for shoots that developed from cuttings with the greatest amount of exposed material.

DISCUSSION

This study was conducted to determine the optimal dimensions for maximizing survival and growth of unrooted cuttings of black willow grown as a short rotation renewable energy crop. Results were analyzed to determine the most favorable size of vegetative planting stock along with its planting depth for survival and growth enhancement. An understanding of how size of vegetative planting material influences survival and shoot growth will enable development of plantation establishment protocols for advanced experimentation on other aspects of plantation production, such as genetic screening trials. It was hypothesized that long cuttings with large diameters would exhibit the greatest survival and shoot growth.

Cutting length was the most influential factor on black willow shoot height and diameter growth in this study, with the longest cuttings showing the greatest growth. This finding may relate to the amount of root mass that developed on the rooting zone of longer cuttings. Our personal observations indicate black willow will root along the entire length of the below-ground portion of the cutting. One limitation of this study is that we only measured trees over a two year study period. Our results indicate that initial differences due to cutting length may be decreasing over time. Additional years of measurements may demonstrate that longer cuttings only benefit shoot growth in the first few years of plantation establishment. Shorter cuttings may prove to be just as tall in 3 to 5 years, which is harvesting age for other willow biomass crops (Abrahamson et al. 2002).

We cannot explain why cutting diameter was not a more influential factor on black willow shoot growth. Our results indicated that the smallest cutting diameters yielded the tallest shoots, but we did not observe a linear trend of stem growth among treatment levels. While small diameter cuttings exhibited good shoot growth, cuttings of very small diameter could easily break during planting.

As with cutting diameter, we expected planting depth to have more of an influence on shoot growth than observed in this study. It is likely that a greater response would have been observed on a site with lower soil moisture availability. The practical limitation on planting depth is that the longer a cutting is, the more energy and time it takes to plant. Deeper planting depths would increase planting cost. On sites with less annual rainfall, deeper planting depths would likely be required to keep survival high. It is hypothesized that on less mesic sites survival would decrease.

CONCLUSIONS

This study demonstrates relatively long black willow cuttings developed shoots that were taller and with a larger diameter than relatively short cuttings. In contrast, cutting diameter and planting depth did not influence growth to the same extent. Furthermore, cutting dimension did not impact black willow survival. The recommendation from this study is to plant longer cuttings for increased height growth in biomass plantations of black willow. Results from this study indicate that height growth of black willow can be maximized with cuttings that are 21 inches long, 3/8 inches in diameter, and planted to leave 8 inches of exposed material above the ground. Future measurement of this study will reveal if our findings are maintained over longer periods of plantation development. Additionally, we plan future work to evaluate optimization of cutting size with horizontal and vertical planting techniques to minimize planting cost.

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Table 1—Mean height and diameter of black willow shoots by cutting length treatment levels 1 and 2 years after planting

Cutting Length (in)	Year 1		Year 2	
	Height (ft)*	Diameter (in)	Height (ft)	Diameter (in)
9	8.5 a	0.92 a	15.8 a	1.74 a
15	8.9 b	1.00 b	16.1 b	1.81 a
21	9.5 c	1.09 c	16.4 c	1.87 b

* Significant differences (p<.05) are indicated by different letters following the means in a column.

Table 2—Mean height and diameter of black willow shoots by cutting diameter treatment levels 1 and 2 years after planting

Cutting Diameter (in)	Year 1		Year 2	
	Height (ft)*	Diameter (in)	Height (ft)	Diameter (in)
3/8	9.2 a	1.06 a	16.4 a	1.90 a
1/2	8.9 b	0.97 b	15.9 b	1.75 a
3/4	9.0ab	1.02 ab	16.0 b	1.80 b
1	8.9 b	1.00 b	16.0 b	1.78 b

* Significant differences (p<.05) are indicated by different letters following the means in a column.

Table 3—Mean height and diameter of black willow shoots relative to amount of exposed cutting material above ground 1 and 2 years after planting

Exposed Material (in)	Year 1		Year 2	
	Height (ft)*	Diameter (in)	Height (ft)	Diameter (in)
2	8.9 b	1.00 a	16.0 a	1.79 b
5	9.1 ab	1.02 a	16.1 a	1.80 ab
8	9.1 a	1.03 a	16.2 a	1.85 a

* Significant differences (p < .05) are indicated by different letters following the means in a column.