THE EFFECTS OF HARVESTING SHORT ROTATION COTTONWOOD WITH TREE SHEARS IN ARKANSAS

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Abstract—Short-rotation cottonwood plantations were established on a marginal agricultural site in the lower Mississippi Alluvial Valley in southeast Arkansas using two known clones (S7C20 and ST-66) and nursery-run cottonwood stock (MIXED) from the Louisiana Department of Agriculture and Forestry nursery. The cottonwood was grown for five seasons and harvested in the winter of 2013-2014. Harvesting was done by a chainsaw (control) and a mechanical tree shear (treatment). Regeneration in the form of stump sprouts was evaluated after one growing season for survival, total number of sprouts, sprouts taller than 137 cm (4.5 feet), ground line diameter, diameter at breast height (4.5 feet) and total height. Harvesting cottonwoods using tree shears significantly increased mortality, and decreased number of sprouts and diameter and total height of sprouts one year after harvest.

INTRODUCTION

The growing demand for renewable energy is driving the development of dedicated agricultural and forestry systems producing biomass for energy. The Lower Mississippi Alluvial Valley (LMAV) region has great potential for biomass production due to a lengthy growing season, well-developed agricultural industry, and excellent transportation and energy distribution systems (Trip et al. 2009). A biomass production system based on two native species, cottonwood (*Populus deltoides*) and switchgrass (*Panicum virgatum*) was established on marginal soils in the LMAV in 2009 (Pelkki et al. 2009). This particular site was considered marginal due to low productivity and the difficulty in irrigating this site because of its location. Bioenergy systems in the LMAV have the potential to increase farm revenues and by producing biomass for energy on lands that are considered unacceptable for row crop production we can avoid a “food vs. fuels” conflict (Blazier et al. 2014).

The long-term sustainability and economic returns of such agroforestry systems depends on adequate survival and natural regeneration from coppice regenerated cottonwood trees (Liechty et al. 2012). Unless multiple generations of cottonwood biomass can be produced from a single, initial planting, the cost of the establishment and production of cottonwood biomass is too great to justify use in bioenergy production. In this study, first rotation costs of cottonwood establishment and management produced biomass that cost $65 to $140 per oven-dry metric ton in the first rotation. These costs can be reduced to as little as $20-26/ODMT on the stump if four rotations of cottonwood can be harvested from the same stool bed (Liechty et al 2012).

In Europe a great deal of small scale harvesting equipment is commercially available for bioenergy harvesting (Ehlert and Pecenka 2013, Vanbeveren et al. 2015). While these systems can be purchased in the United States, they often cost in excess of $75,000, so we chose to use a harvest system that could be mounted to a tractor of typical size on most farms in the United States.

This research study focuses on the post-harvest survival and growth of three cottonwood clones after harvesting using two different techniques, hydraulic tree sheers or chainsaws to sever the tree from the root system. The objectives of this study are to test for treatment differences in survival, number of sprouts, and height and diameter growth in the initial year after harvest.

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METHODS

In 2009, two known cottonwood clones (S7C20 and ST-66) were planted along with a nursery-run of mixed cottonwood clones (MIXED) from a state-run tree nursery in northwest Louisiana. The trees were planted on the University of Arkansas's Southeast Research and Extension Center Desha County, Arkansas. The site was an abandoned row crop field with Sharkey and Desha clay soils. Pre-planting herbicides burned down all competition, and the site was ripped to a depth of 36 cm prior to planting on a 1.22m x 1.83m spacing, or 4480 trees per hectare. Alternating rows contained ST-66, S7C20, and MIXED trees, and overall plot sizes were 30m by 90m.

During the first rotation, pre-emergent herbicides were applied in the first and second growing season to control competition. At the start of the second growing season, a banded ammonium nitrate application of 168 kg/ha was applied as a fertilizer. During the second growing season, a cottonwood leaf beetle infestation was controlled with an insecticide application.

In 2009, in each of three replicated 30x90m plots, 60 trees of each clone were selected for the study, for a total of 180 trees. These trees were monitored annually for survival and growth in total height (THT), ground-line diameter (GLD) and diameter at breast height (DBH). After five growing seasons, in November/December of 2013, half the trees were selected for harvest by chainsaw felling (by hand) and the other half of the trees were harvested by a hydraulic shear mounted on a trac-loader. This tree shear, a Hydra-Snip manufactured by M&M Engineered Products, LLC in Coffeyville, Kansas, is capable of being mounted on a front-end loader equipped tractor. It is capable or cutting a 12" diameter stem in a single pass. The cost of this shear was under $15,000, making the capital investment for a bioenergy harvest system much lower than other options.

After one growing season, the trees were measured for survival, total number of live sprouts, total number of sprouts with height greater than 137 cm (breast height), total height of tallest sprout, and ground line diameter (GLD) and diameter at breast height (DBH) of the tallest sprout. Two way analysis of variance for main and interaction effects (replication and clone) was completed with SYSTAT 13 software.

RESULTS AND DISCUSSION

Of the 180 trees that were planted in 2009 as part of this study, survival was acceptable, averaging 84 percent after the first year (table 1). From 2010-2013, only another 2 percent of the trees died, leaving 148 of the original 180 trees alive to be harvested in 2013. Prior to harvest, there were no significant differences in trees' diameters by their assigned treatment or clone. However, all trees in replication three were significantly taller than trees in replications one and two. It should be noted that while the study site had very little slope (0-1 percent), it did drain through the third replication's plot.

Stump height was only loosely controlled during the harvest. The chainsaw fellers had instructions to leave a stump with a height of 5-10 cm and the shear operator was instructed to leave as short a stump as possible without cutting below the ground line. Post-harvest analysis showed shear stump heights from 5-15 cm with an average of 10cm, and chainsaw stump heights ranged from 5-10cm with an average of 8 cm. No significant difference was found in stump heights in any treatment or clone.

One year after harvesting, there was a significant harvest effect on mortality (table 2). There was a significant increase in mortality among those trees harvested using tree shears ($p<0.001$). It was also noted that the MIXED trees had a significantly higher survival ($p=0.034$) and that replication three had greater survival ($p<0.001$) than replications 1 and 2. Replication three was the wettest of the three replications, located at the point where the entire field drained into an irrigation ditch.

There was no significant difference ($p=0.096$) in the treatments in the number of large sprouts (THT ≥ 137 cm) among the treatments, nor was there a significant difference ($p=0.697$) in the total number of all sprouts between the two treatments (table 3). Replication 3 did have fewer large sprouts ($p=0.02$) and fewer total sprouts ($p<0.001$) for all genotypes. As the drainage for the study site ended near the plot for replication 3, this site was under water the longest in the spring after harvest, which delayed all cottonwoods from sprouting as early as those in replications 1 and 2.

Shearing had a negative effect on both ground line diameter (GLD) and diameter at breast height (DBH) as shown in table 4. Total height ($p<0.001$) and diameter at breast height ($p=0.001$) were reduced in all clones by harvesting with tree shears. The ST-66 clone also had an interaction effect with shearing ($p=0.024$) on ground line diameter.

Finally, total tree height after one growing season was negatively affected ($p<0.001$) by harvesting the trees using tree shears (table 5). While after five growing seasons the trees in replication 3 had significantly greater total height, this effect was not apparent one growing season after harvest.

CONCLUSIONS

The tree shears used were quite new and the blades very sharp, minimal stump damaged was observed from

Table 1—Survival of three planted cottonwood genotypes in southeast Arkansas over a five-year rotation

Genotype	2009 Planted	End of 2009 Live Trees	End of 2013 Growing Season (pre-harvest) Live Trees (% Survival of trees planted in 2009)
CHAINSAW HARVESTED TREES (CONTROL)			
ST-66	30	22	22 (73%)
S7C20	30	28	27 (93%)
MIXED	30	28	28 (93%)
TREE SHEAR HARVESTED TREES			
ST-66	30	23	23 (77%)
S7C20	30	27	26 (90%)
MIXED	30	23	22 (77%)

Table 2—Survival of three cottonwood genotypes one year after harvesting with chainsaw and tree shear in southeast Arkansas

Treatment: Chainsaw (control)				
	Pre-harvest		Post-harvest	
Clone	Count	% Survival (trees alive in 2013)	Count	% Survival of trees harvested in 2013
ST-66	22	100%	22	100%[a]
S7C20	27	100%	26	96%[a]
MIXED	28	100%	28	100%[a]
Treatment: Tree Shear				
	Pre-harvest		Post-harvest	
Clone	Count	% Survival (trees alive in 2013)	Count	% Survival of trees harvested in 2013
ST-66	23	100%	16	69%[b]
S7C20	26	100%	19	73%[b]
MIXED	22	100%	19	86%[b]

Survival percentages with different superscripts are significantly different at $\alpha = 0.05$

Table 3—Number of large sprouts (THT ≥ 137 cm) per stump and number of total sprouts per stump on cottonwood genotypes one year after harvest in Southeast Arkansas

Large Sprouts (THT ≥ 137 cm)		
	Harvest Method	
Clone	Chainsaw	Tree Shear
ST-66	3.3[a]	2.8[a]
S7C20	5.0[a]	2.3[a]
MIXED	3.4[a]	2.2[a]
All Live Sprouts		
	Harvest Method	
Clone	Chainsaw	Tree Shear
ST-66	7.1[b]	6.1[b]
S7C20	6.4[b]	7.1[b]
MIXED	4.9[b]	6.7[b]

Numbers of sprouts with different superscript are significantly different at α = 0.05.

Table 4—Ground line diameter and diameter at breast height of the tallest sprout one year after harvesting with chainsaw or tree shears for three cottonwood genotypes in southeast Arkansas

Ground Line Diameter (mm)		
Clone	Harvest Method	
	Chainsaw	Tree Shear
ST-66	24.61[a]	17.13[c]
S7C20	24.60[a]	20.90[b]
MIXED	26.29[a]	22.53[b]
Diameter at Breast Height (mm)		
Clone	Harvest Method	
	Chainsaw	Tree Shear
ST-66	10.21[d]	8.84[e]
S7C20	12.17[d]	9.13[e]
MIXED	11.48[d]	9.23[e]

Numbers of sprouts with different superscript are significantly different at α = 0.05.

Table 5—Total height of the tallest sprout one year after harvesting with chainsaw or tree shears for three cottonwood genotypes in southeast Arkansas

Total Tree Height (cm)		
Clone	Harvest Method	
	Chainsaw	Tree Shear
ST-66	231[a]	202[b]
S7C20	228[a]	201[b]
MIXED	227[a]	203[b]

Tree heights with different superscript are significantly different at α = 0.05.

the shears and by the following growing season, it was impossible to distinguish between chain sawed stumps and sheared stumps. The harvests took place during November and December of 2013, the soil was quite saturated with water though rutting in the site from the trac-loader was minimal. However, soil displacement might have caused some damage to trees harvested in this fashion.

The mortality caused by the tree shears is substantial. After five years in the first rotation, 86 percent of the trees (77 or 90) in the three plots assigned to be chain saw felled were alive. This is a good level of stocking. One year after harvest, 84 percent of the trees (76 of 90) were alive and this is still a good level of stocking for the second rotation. In the three sheared plots, 79 percent of the trees were alive (71 of 90) at the end of the first rotation. One year after harvest with the tree shears, only 60 percent of the stems (54 of 90) were alive. The additional mortality that is attributed to the harvest method would require supplemental planting to maintain full site utilization and this would raise costs of biomass production.

We did not test the impact of harvest timing on cottonwood mortality. Both the chainsaw felling and shearing took place in November and December, and at the time the trees appeared fully dormant. If harvest were to occur in early September at the end of the growing season, the soil on this site would not be as wet, soil disturbance impacts would likely be minimized, and mortality from the equipment might be less.

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