Black Willow Biomass Feedstock: *Progress & Questions*

One of the keys to a successful biofuels industry is the accessibility of reasonably priced raw material. Dedicated energy plantations in close proximity to a biofuels facility could provide a substantial portion of that type of material. At this point, it is uncertain where these facilities might be built, but developing an array of fast-growing biomass species will provide the diversity of raw material that these facilities will need in the future.

The forestry department at Mississippi State University has been evaluating a number of species, planting designs, and mixtures of feedstocks. These trials have included eastern cottonwood, hybrid poplars, black willow, and loblolly pine. In addition, studies examining loblolly pine in combination with an energy crop such as switchgrass are also under way. This report is the first in a series that will list the research progress and questions concerning other potential viable biomass feedstocks.

This report addresses black willow and the current research efforts that have been undertaken to develop this species into a viable feedstock for the bioenergy and biofuels industry. Black willow possesses a number of traits such as rapid growth, excellent rootability, ease of vegetative propagation for producing clones, and the ability to be coppiced (sprouting from stumps following harvest), all of which are positive aspects for a biomass species. However, what may be the most important trait of black willow is its ability to grow on poorly drained, heavy clay sites that are unsuitable for agronomic crops, energy grasses, and most fast-growth tree species.

Project Description

In 2009, the Mississippi State University Department of Forestry and the USDA Forest Service Center for Bottomland Hardwood Research began a project focused on the development of a small group of genetically superior black willow clones for the Lower Mississippi River Alluvial Valley.

Genetic studies, such as screening and clone trials, need to be observed for a number of years to ensure sound selection of superior genetic stock. Unlike agronomic row-crops, trees are long-lived organisms, and while the focus of this project is the production of biomass over a short rotation of 2 to 5 years, it will take multiple years to determine potential growth and disease resistance.

In addition, acquiring testing material from natural stands and then increasing the number of each individual (a clone) for testing will take at least 1 year and often multiple years. It is important to understand that to determine the true genetic performance of an individual, it must be tested over a number of different sites over time. The goal through this type of testing is to eliminate most, if not all, of the environmental components, thus providing a clear understanding of the genetics.

Figure 1. Two-year-old black willow test planted at 6-by-9 feet and located at the Delta Research and Experiment Station in Stoneville. Photo taken in February 2012, prior to the third growing season.

Research Activities

To find superior black willow clones, a sampling was used to take advantage of the known performance and genetic information concerning geographic origin of eastern cottonwood clones. This led to the sampling of five geographic areas in three states that included four stands per geographic area and five clones per stand. A more thorough description of the areas sampled can be found in MSU Extension Publication 2653 *Black Willow as Biomass*.

To test this material, each individual was cloned and included in a total of four screening trials established in 2010 and 2011. These clonal screening trials were initially employed due to the low number of clonal copies needed for each individual. This type of trial allows the inclusion of all 113 individuals on multiple sites each year. The two screening trials in 2010 were placed on Mississippi agricultural experiment stations near Prairie and Stoneville. In 2011, one screening trial was established on a former rice field near Hollandale, and a second trial was located near Prairie.

Although the oldest of these four screening trials is only 2 years old, some results have been observed. The most striking result from these trials has been the extremely high survival rate, averaging approximately 99 percent. Enhanced rooting is a characteristic that must be tested and selected for in eastern cottonwood, so that survival does not greatly impact yields. The excellent rooting characteristics of dormant unrooted black willow cuttings will play an important role in greater per-acre yields due to high survival. This trait is an extremely positive aspect for black willow as a viable biomass species.

Total height for the five geographic sources showed that the two most southern areas, near the coast of Louisiana and near Houston, Texas, were the tallest at ages 1 and 2. The Texas source was the tallest, averaging more than 15 feet on the Stoneville test site at age 2. While the growth of this species looks good, it is not as good as the growth of eastern cottonwood. When eastern cottonwood is planted on a good site, it will average in excess of 20 feet for total height at age 2.

The seven tallest 2-year-old clones from the 2010 trial at Stoneville averaged nearly 16.5 feet, with the tallest clone averaging more than 17 feet. Although this height was not attained at the Prairie test site, four of the top seven clones at the Stoneville site were among the seven tallest at the Prairie site. **It is important to note that the sites where these black willow trials are located would be considered, for the most part, marginal agriculture land.**

During the measurements of the four trials, researchers observed that the trees do not seem to be using the available growing space (**Figure 1**). This unused space has led to questions concerning planting density. Tests were planted at a 3-by-9-foot spacing, or approximately 1,613 trees per acre. In comparison, eastern cottonwood on short-term rotations of 3 to 4 years does well at a 6-by-9-foot spacing, or 806 trees per acre.

On good sites found between the levee and the Mississippi River, eastern cottonwood at a spacing of 6-by-9 feet would exhibit crown closure during the middle portion of the second growing season. Fortunately, there was a study planted in 2012 by the USDA Forest Service in conjunction with Mississippi State University that examines planting densities of black willow and eastern cottonwood.

As mentioned previously, the goal of any forestry improvement program is to select the best individuals to regenerate new stands. Included in this goal is the understanding that time is money. As such, geneticists use statistical and molecular methods in selecting the best individuals in the least amount of time. Eliminating poor individuals early in the testing stage allows us to focus our efforts on those that have the greatest potential.

In forestry, it is known that age-1 measurements are extremely unreliable in predicting latter age performance, even for short-term rotations of 10 to 12 years. However, the goal of this program is focused on testing clones at rotation lengths of one-third to one-half of a 10-year rotation; therefore, the decision was made to use available data, which is the age-2 height and diameter from the 2010 trials, and incorporate the age-1 data from the 2011 trials to form the first attempt at defining the best 25 clones to test further.

A highly replicated clone test was established in 2012 using the 25 fastest growing clones from the screening trials. While these five studies are the foundation of our current black willow improvement program, it is our expectation that based on the 2- and 3-year data from the 2010 and 2011 trials, a set of highly replicated clone tests will be established in 2013.

In addition to the clonal testing, a study established in 2009 examined the optimal cutting size of black willow planting stock and noted rooting characteristics of unrooted dormant black willow cuttings. The 2009 study examined three different cutting lengths, four diameter sizes, and the planting depth of the cutting. After 2 years, it became apparent that the longer cuttings resulted in better growth, but cutting diameter had little effect.

These findings provided the stock size needed to ensure high survival and rapid growth. The shorter the cuttings, the greater the number of cuttings that can be produced from a single black willow whip, which is important if high tree densities are expected to be planted. Unrooted cuttings' rooting characteristics were further examined in rooting benches. The location of roots along the cutting was similar to that seen in cottonwood, with the greatest number of roots forming on the portion of the cutting deepest below the surface, with root numbers decreasing on the cutting as the distance from the deepest end increased; however, the amount of root biomass produced by black willow is exceptionally higher that eastern cottonwood and forms in a much shorter period of time.

These findings provide the understanding of the high survival rates seen in the genetic trials and cutting size study. Yet, this also raises the question: "With this exceptional rooting, is there a way to more efficiently use cuttings?" To answer, cuttings were placed horizontally in rooting beds at various depths. These cuttings were rooted well and were able to emerge from even the deepest depth. One aspect observed was that the cutting rooted similar to those placed vertically, but each bud section produced shoots.

This observation led to the testing of small, single-node cuttings placed horizontally. The successful performance of these single-node cuttings in the rooting benches has led to a small field trial established in 2012. If this is successful, it could play a critical role in black willow biomass plantations. Not only would it reduce the stock cost, but exceptionally high clay soils could easily be planted over a much wider array of soil conditions.

Summary

Black willow exhibits a number of characteristics potentially suited to making it a viable biomass feedstock for bioenergy and biofuels. A search for superior black willow clones is currently under way, with the examination of 113 clones being tested in four trials. The top 25 clones will be selected and more intensively tested.

In addition, a regeneration study examining the optimal cutting size showed great success with a variety of dormant unrooted cuttings. However, there are still questions concerning genetic selections, growth rates, spacing, and rotation length. The work at Mississippi State University will continue to explore and evaluate these aspects.

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