Developing a Willow Biomass Crop Enterprise in the United States

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Abstract

More than two decades of research on woody crops, combined with growing concern about environmental issues, prompted the formation of the Salix Consortium in 1994. Over 20 organisations have pooled their resources and talents to facilitate the development of willow biomass crops as a locally grown source of renewable energy and cellulose feedstock that produces multiple benefits for the northeastern and midwestern regions of the United States. State University of New York College of Environmental Science and Forestry (SUNY-ESF), and other Salix Consortium partners, continue to develop and expand a strong applied research program, which underpins the commercialisation effort. Research focuses on both optimizing the production system and quantifying environmental benefits associated with willow biomass crops.

In 1998 and 1999 over 120 ha of willow biomass crops were established in western New York in close proximity to a coal-fired power plant. The power plant is being retrofit for co-firing wood biomass with coal, with initial tests scheduled for the spring of 2000. Continuing research gains in crop yields and reductions in costs, and supportive state and national policies that value the environmental and rural development benefits, will be essential to making a commercial willow biomass enterprise successful.

Background

The development of a willow biomass production system for the northeastern and midwestern United States is based on almost two decades of research at the State University of New York College of Environmental Science and Forestry (SUNY-ESF). Research has ranged from trials with hybrid poplar at relatively wide spacing and anticipated 10- to 12-year rotations (Abrahamson et al. 1990) to willow trials at extremely high densities and 1-year rotations (Kopp et al. 1993). As this research began to yield encouraging results, and concern about environmental issues grew, interest developed in the concept of a rural-based enterprise centered on willow biomass as a renewable source of energy and cellulose feedstock for bioproducts. In 1993 SUNY-ESF, in conjunction with Niagara Mohawk Power Corporation (NMPC), New York State Electric and Gas (NYSEG), and the New York State Research and Development Authority (NYSERDA), formed the Salix Consortium (originally called the Empire Power Consortium). In 1995, the Salix Consortium conducted and submitted a feasibility study on the development of a willow biomass crop enterprise in New York state (Neuhauser et al. 1995). The project was one of three competitively bid, national projects selected to demonstrate the development of a dedicated feedstock energy project under the United States Departments of Energy and Agriculture Biomass Power for Rural Development program. Support has been received from a variety of additional sources including NYSERDA, Electric Power Research Institute (EPRI), the U.S. Forest Service, Oak Ridge National Laboratory, and others. During this program, the Consortium will investigate and assess critical aspects and questions concerning the commercial development of willow biomass for power generation and the multiple benefits to the environment and local economy.

The Salix Consortium

The goal of the Salix Consortium is to facilitate the development of willow biomass crops as a locally grown source of renewable energy and feedstock for bioproducts that produces multiple benefits for the northeastern and midwestern regions of the United States. The Salix Consortium currently pools the research and investment interests of over 20 corporations, associations, universities, conservation groups, environmental organisations, and regional and national government agencies to develop this crop to a pre-commercial demonstration and commercial production stage (White et al. 1999). Participation in the Consortium has shifted since its inception, particularly as the energy industry in New York and other states undergoes restructuring.

The challenge facing the Salix Consortium is to simultaneously optimise production and utilisation technology, develop farmer interest, increase crop acreage, and add a new fuel to the power supply providing long-term markets for producers. The scenario is challenging because currently there is not enough willow biomass established to fulfill a power producer's needs, while at the same time there are no long-term agreements/commitments that will assure producers of a stable market in the future for their crop. In order to be successful, the participation of farmers and landowners, businesses, and local and regional governments is essential. The Consortium has designed and implemented a three-phased approach to elicit this participation (Volk et al. 1999). The avenues include a focused outreach and education effort, the active involvement of potential producers of willow biomass crops, and the development of an economic and business opportunity model for willow biomass crops.

The willow biomass production system being developed is based on SUNY-ESF's years of research, as well as extensive work in Sweden (Larsson et al.1998), the United Kingdom (Armstrong et al. 1999), and Canada (Kenney et al. 1996). Its basic characteristics are double row mechanical planting of 15,300 plants/ha and mechanical harvests on three- to four-year cycles (Volk et al. 1999). Willows were selected for the northeastern and Great Lakes regions of the United States over other woody species because of their rapid juvenile growth rates, vigorous coppicing ability, ease of establishment from unrooted cuttings, and high potential for rapid genetic improvement. Yields of fertilised and irrigated willow grown for three years have exceeded 23 odt ha^{-1} yr^{-1} (Kopp et al. 1997). First rotation, unirrigated trials in central New York have produced yields of 8.4 to 11.6 odt ha^{-1} yr^{-1} (Adegbidi 1999). It is anticipated that second rotation yields will increase, while commercial yields will be slightly lower due to variability in field conditions. Yields of the first large-scale trials will be available in the winter of 2000/01. Improved willow clones that will increase yields will be available soon from ongoing breeding efforts at SUNY-ESF. Additional improvements in yields should be realised by optimizing the production system in terms of weed control, clone-site interactions, fertilisation, and integrated pest management.

The near-term energy market strategy that the Salix Consortium is focusing on for willow biomass is co-firing at pulverised coal power plants. The 104 MW Greenidge pulverised coal power plant in central New York was retrofit and has demonstrated continuous co-firing of wood at 10% by heat input for over three years now. A successful test firing of willow biomass at Greenidge has been performed. This experience has provided insight into the remaining issues to be addressed in order to assure efficient use of the willow energy crop. As a part of utility restructuring in the state, NYSEG sold the Greenidge power plant to Atlantic Electric Service (AES). While this plant remains a potential market for willow biomass, the future participation of the new owners is still being defined. NMPC successfully completed wood co-firing tests at the 400 MW Dunkirk power station in western New York state. The station's new owner, NRG Energy Inc., will continue with the retrofit of one 96 MW boiler at the station. Test burns using willow and other wood biomass are planned for the spring of 2000. The immediate fuel for co-

firing will be wood residues from the forest products industry, with willow biomass becoming a part of the mix in 2001 when the first large area of willow biomass crops are harvested.

A major benefit of the willow biomass cropping system is that environmental and social benefits, in addition to the renewable energy and bioproducts, can be produced simultaneously. The production, quantification, and valuation of these benefits is essential in order to make the system economically viable under the current electric energy industry structure in the northeastern United States. SUNY-ESF is actively pursuing and researching some of these additional benefits including

- Quantification of changes in soil carbon under willow biomass crops over time,
- Phytoremediaiton of contaminated sites with willow biomass crops,
- The use of willows as nutrient filters in riparian zones and as part of on-farm manure management systems,
- The use of willow and poplar as an alternative cover for landfills,
- The application of biosolids on willow biomass crops, and
- The development of living willow snow fences.

Efforts are under way to assess the rural development benefits in terms of job creation and new tax revenue that will accrue from the development of a willow biomass enterprise (Proakis et al. 1999).

A major task for the Salix Consortium during the Biomass Power for Rural Development demonstration project will be to show that willow energy crops can compete as a fuel in a restructured industry where emphasis is placed on obtaining the lowest energy production cost. The key to accomplishing this will be translating as many of the environmental and social benefits of a willow biomass enterprise into measurable items that can contribute to the bottom line. For example, the Consortium's objective of demonstrating a delivered fuel cost of under $2.00/MMBtu for willow (White et al. 1995) would be a major step forward for energy crop development. However, on average, that price is still $0.50 to 0.60/MMBtu more expensive than coal under long-term contracts in New York state. To compete in the current energy and bioproducts market, policy makers must be convinced that tax incentives, emission credits, and other approaches to valuing environmental and social benefits associated with a willow biomass are necessary to develop the enterprise.

Recent Program Developments

Research Program

Since the inception of the Biomass Power for Rural Development program, significant progress has been made at both the production and energy conversion use ends of the enterprise. SUNY-ESF and other Salix Consortium partners continue to develop and expand a strong applied research program, which underpins the commercialisation effort. Research focuses on both optimizing the production system and quantifying environmental benefits associated with willow biomass crops (Table 1). Results to date have been translated into initial recommendations for scale-up activities.

Planting Stock Production

Planting stock production for willow biomass crops currently occurs at two facilities in New York state: The New York State Department of Environmental Conservation's Saratoga Tree

Table 1. Research under way by SUNY-ESF and other Salix Consortium partners

Study title currently	Willow Production system benefit	Issue addressed
	Production system research	
Genetic Improvement of Willows via Interspecific Hybrids and Intraspecific Crosses	A strong clonal improvement program will help ensure increases in productivity and clone survivability. This will have a positive impact on production costs.	Inheritance patterns of traits important to biomass production. Molecular markers will be identified to ultimately serve to accelerate genetic improvements.
Integrated Pest Management in Willow Biomass Crops	Pest management ensures high willow survivability and productivity.	Identification of pests and diseases impacting various willow clones and designing control strategies to minimise impacts.
Effect of Slow-Release Nitrogen Fertilisation on Aboveground Biomass Production	Slow-release nitrogen will improve yields and be less environmentally detrimental than other types of N fertiliser.	Recommended rates of nitrogen fertiliser application to optimise biomass production rates of willow.
Use of Biosolids as Organic Soil Amendment in Willow Bioenergy Plantations	Lower production costs by replacing commercial nitrogen fertilisers and provide a productive use for biosolids.	Mineralisation rates of nitrogen from biosolids, heavy metal and nutrient movement, and willow growth response.
Alternative Methods of Site Preparation	Minimise soil erosion and reduce site preparation costs.	Aboveground biomass production of different site preparation methods.
Cutback After First Year Growth	Reduce operational costs and potential compaction of wet soils during the fall.	Impact of cutback versus no cutback treatment on survival and biomass production of five willow clones.
Clone-Site Testing and Selections for Scale-up Plantings	Establishing parameters for clone to planting site relationships will enhance yields and reduce production costs.	Survivability and yields of various clones over wide range of climate and soil conditions.
Clonal Selection Trial and Studying the Ecophysiological Basis for Relative Productivity	Understanding factors affecting yield will improve selection of new clones and help modify management practices to improve yield.	Seasonal variations in physiological and environmental parameters will be characterised.
Aboveground Biomass Equation Development for Five Salix Clones and One Populus Clone	Accurate estimation of biomass yields before harvesting will be important in establishing contracts and economic modeling.	Design protocols and develop equations for non-destructive estimation of biomass yields.
Field Production Equipment Improvement (Cornell University)[a]	Optimise planting and harvesting rates while minimizing impact on fields and willow crop.	Increased productivity, lower final product costs, long-term sustainability.
Effect of Storage Conditions on the Survival and Growth of Willow Cuttings	Vigorous and viable cuttings for planting stock are critical to the commercial success of willow production.	Length of time cuttings can be left out of storage during planting season without losing viability.
Effectiveness of Different Weed Control Practices in Willow Biomass Crops	Optimised weed control practices will ensure crop survival, higher yields, and lower production costs.	Effectiveness of different mechanical and chemical weed control practices.

Table 1 (continued)

Study title currently	Willow Production system benefit	Issue addressed
Environmental studies		
Impact of Willow/Poplar Biomass Crops on Diversity of Soil Microarthropods	Quantification of the sustainability of willow biomass systems.	Belowground biodiversity impact of sustained willow production.
A Study of Avian Biodiversity in Short Rotation Intensive Culture Willow Plots (Cornell University)	Address concerns raised about the impact of willow crops on avian biodiversity.	Impact of sustained willow production on bird populations and diversity.
Soil Sustainability and Productivity in Willow and Poplar Biomass Crops	Address concerns raised about sustainability and quantify soil carbon sequestration.	Evaluate the impact of willow on soil carbon and sustainability over time.
Root Dynamics in Willow Biomass Crops	Will assist in valuing carbon sequestration benefits of willow and assist in optimizing management practices.	Improve understanding of fine root longevity, distribution, biomass, and turnover.

[a]Studies listed are being lead by SUNY-ESF unless other institutions are noted.

Nursery (STN) and the SUNY-ESF's Tully research station. Cutting orchards, irrigation systems, and cold storage facilities have been developed at both locations to support these operations. In the winter of 1998/99 almost 1.5 million cuttings (records are kept on the number of 25-cm long cuttings or the equivalent in rods or whips) were produced at the two locations (Table 2). This represents an increase of 85% from 1997/98. Increases were due to maturing of cutting beds established in 1996, partial production from beds established in 1997, and irrigation system improvements at STN. Cuttings made from first-year coppice material in central and western New York added another 110,000 cuttings to the supply. The implications for producing cuttings from dedicated beds is that a two- to three-year lead time is required to bring the beds into full production. However, the higher density (30,000 to 35,000 plants ha^{-1}) and concentration of effort at central locations, compared with the commercial planting density of about 15,300 plants ha^{-1} at scattered locations, increases the efficiency of the operation. Initial assessments indicate that the cost per cutting is reduced by 10 to 17% when whips rather then cuttings are produced. Production costs for material from cutback operations is up to 100% greater than material from cutting orchards due to increased labor and transportation costs.

Table 2. Cutting and whip production in 1998 and 1999 at SUNY-ESF and the Saratoga Tree Nursery in New York state

	SUNY-ESF		Saratoga tree nursery (STN)		Total
	1998	1999	1998	1999	1999
Cuttings[a]	257,000	225,000	375,000	446,000	671,000
Whips/rods[a]		300,000	175,000	528,000	828,000
Total	257,000	525,000	550,000	974,000	1,499,000

[a]Data presented are for 25-cm-long cuttings or the equivalent number in whip sizes.

Demonstration Areas in Western New York

In 1998 the Salix Consortium planted over 45 ha of willow biomass crops with modified Froebbesta planters in western New York. In 1999 an additional 80 ha of land was planted to willow biomass crops using a newly acquired Step planter and the older, modified Froebbesta planters. Field assessments indicate that the Step planter operated at a rate of 1.0 ha hr^{-1}, including time for reloading and turning around at the end of the fields. The rate for the modified Froebbesta planters was 0.25 ha hr^{-1}(R. Pellerin, personal communication).

All the areas planted in 1998 and 1999 were within a 60-km radius of the power plant where the biomass will be utilised. All of the sites were in a hay crop the previous year or had been fallow for one to five years. This type of land is common across New York because the agriculture industry, and in particular the dairy industry, has been in decline over the past decade. The 125 ha was spread over seven landowners, with field sizes ranging from 2 to 40 ha. Smaller fields were immediately adjacent to one another. No collection of fields was smaller than 8 ha in size. Four to six different willow clones were planted in each set of fields. One clone of hybrid poplar is being planted and assessed for use in the high-density, double-row system.

Regional Expansion

Interest in willow biomass crops continues to grow across the northeastern and midwestern regions of the United States. Over the past six years, 18 willow clone-site and genetic selection trials have been established in New York, six other states, and the province of Quebec in Canada (Fig. 1). Trials were conducted previously in southern Ontario by the University of Toronto (Kenney et al. 1996). The current clone-site trials range in size from 0.5 to 1.0 ha in size. At each site between 6 and 40 different clones of willow and poplar are being screened for their suitability to different soils and climate conditions.

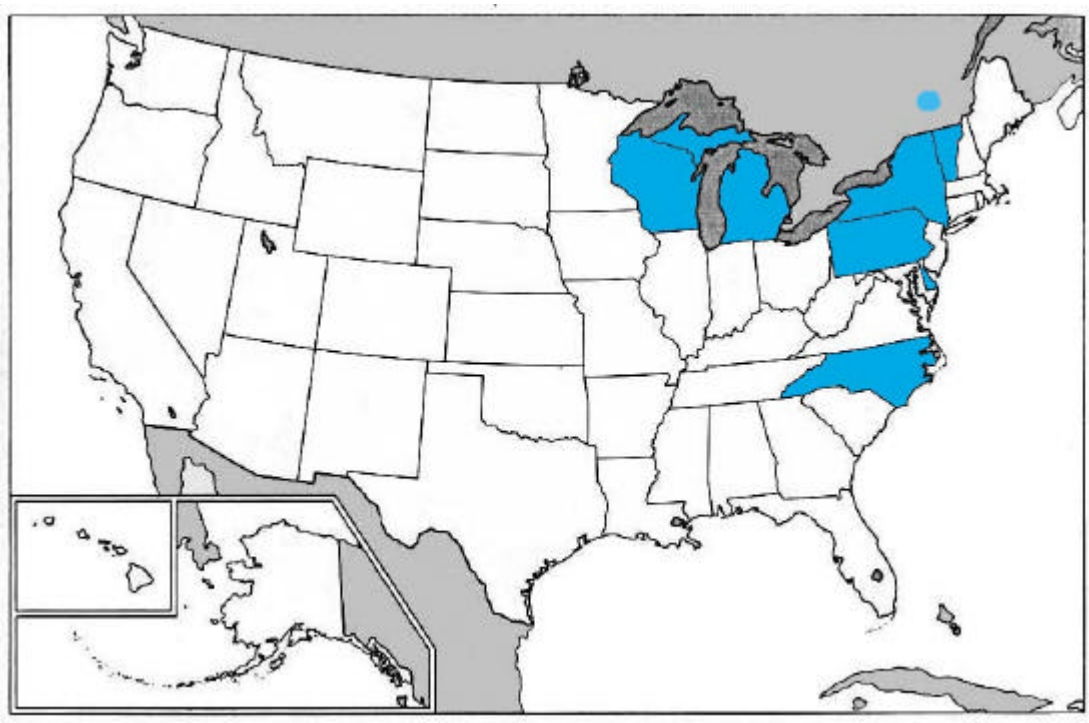

Fig. 1. Locations in the United States and Canada where the SUNY-ESF is participating in willow biomass trials.

Future Plans

Over 130 ha of land have been selected and prepared for planting in the spring of 2000. By 2001 the target under the Biomass Power for Rural Development of over 320 ha of willow biomass crops should be reached. Plans are under way to initiate small trials in two additional states in 2000. Decisions on the harvesting system for use in the demonstration areas will be made by the end of 1999. Machinery will be available for small-scale trials on 3 to 4 ha, in the winter of 2000/01. Harvest of the first 40 ha under the Biomass Power for Rural Development Program will occur in the winter of 2001/02.

The Salix Consortium has made significant progress in developing a willow biomass enterprise. These efforts have received renewed interest with President Clinton's Executive Order of August 1999, which ordered a threefold increase in the use of bioenergy and bioproducts in the United States by 2010. However there are still challenges that need to be overcome, including the stability of energy markets because of the sale of power plants under restructuring. In addition to energy products, the Consortium will continue to quantify and promote the valuation of environmental and rural development benefits associated with the system. Using willow biomass as a feedstock for bioproducts will provide another set of markets. Technological progress and research on cellulosic conversion of willow biomass to high-value chemicals will be helpful in addressing barriers to successful commercialisation utilizing these wood-based renewable resources. However, science alone will not overcome all of the barriers limiting the development of a willow biomass enterprise. Strong federal and state government visions and supportive policies and regulations are necessary to make renewable biomass a viable market competitor to a barrel of oil or a ton of coal.

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