Short-Rotation Woody
Crops Program

at

State University of New York
College of Environmental Science & Forestry

Wood Biomass as an Alternative Farm Product

2001 Annual Report

by:

Timothy A. Volk
Brian D. Kiernan
Lawrence P. Abrahamson
Edwin H. White

March 2002

Prepared for:
United States Department of Agriculture
Cooperative State Research, Education
and Extension Service

INTRODUCTION

Cultivation of willow in the Northeastern and Midwestern United States began in the 1840s by immigrants in western New York and Pennsylvania. By the late 1800s cultivation of willows for basketry and furniture had spread from the shores of Maryland to the western borders of Wisconsin and Illinois. By the early 1900s, New York State dominated willow cultivation in the United States, with 60% of the total reported area, and about 45% of the income generated from willow products. However, as the demand for willow baskets dropped off rapidly in the 1920s and 1930s, only pockets of willow cultivation remained.

The cultivation of willow was revitalized in upstate New York in the mid 1980s at the State University of New York College of Environmental Science and Forestry (SUNY-ESF). The focus was research on the production of willow as a locally produced, renewable, cellulose feedstock for bioproducts and bioenergy. Willow biomass cropping systems also produce valuable environmental and social benefits. These include reduced SO_2 and NO_x power plant emissions and no net addition of CO_2 to the atmosphere when used replacing fossil fuels, such as coal, generate electricity. As an alternative farm crop, it reduces soil erosion and non-point source pollution from agricultural land and enhances agricultural landscape diversity. Willow biomass, as an agricultural crop, has the potential to play a crucial role in revitalizing the economy of rural communities. For every 4,000 ha of willow established in New York, up to 76 jobs and over $500,000 in state and local tax revenue would be created. The production, quantification, and valuation of these benefits are essential in order to make the system economically viable under the current bioproducts and bioenergy industry structure.

Encouraging yields from early willow biomass trials and increasing concerns about environmental impacts associated with the use of fossil fuels led to the formation of the Salix Consortium in 1993. A broad-spectrum of organizations, including farmer groups, environmental organizations, conservation groups, government agencies, research institutions, and industry, are actively involved with the Consortium. Despite the diversity of interests among participants, there is agreement on the following goal: to facilitate the commercialization of willow biomass crops as a locally grown, renewable, cellulose feedstock for bioproducts and bioenergy in the Northeastern and Midwest regions of the United States.

SUNY-ESF, in collaboration with the Central New York Resource Conservation and Development, Inc. (CNY RC&D), continues to conduct an effective outreach, education and technology transfer program. Research results and experience are made available to natural resource professionals, scientists, landowners and the general public in a variety of ways. Attendance and participation at all appropriate conferences, whether international, national or regional, presentations at a wide variety of community gatherings, individual meetings with landowners, reports to stakeholders and refereed journal publications are some of the ways that information from the willow biomass program is disseminated.

Significant progress has been made on both the production and conversion ends of the willow biomass industry. However, economic barriers still have to be overcome to bring willow biomass to the marketplace. The ongoing research and demonstration of willow biomass crops, developments in the biorefinery model and the active participation of a wide array of partners are creating new opportunities to reach the goal of commercializing the system. The development of a vibrant willow biomass enterprise will play an important role in bolstering the farm and forestry sectors, increasing energy independence, providing environmental benefits, and mitigating pollution problems.

EDUCATION AND OUTREACH

Willow Biomass High School Curriculum Modules

As part of an effort to broaden the range of audiences that are effectively being reached by the outreach and education program, a set of science and technology learning modules targeting high school science teachers and students are being developed. The modules focus on the benefits and characteristics of willow biomass crops as a renewable resource and the ecology of renewable energy. They are being designed to incorporate the new Math, Science and Technology (MST) standards for grades 7-12 that are currently being implemented in NY. Due to the lack of available classroom material on the subject, the new MST standards create an opportunity to assist teachers and students on the use of biomass as an energy source. The science and technology modules are being designed to be both teacher and student friendly, incorporate grade-appropriate use of computer technology, correlate each activity to the MST standards, provide creative options for integration with other subject areas and advanced projects, are flexible in sequence, and provide all necessary student worksheets and rubrics for assessment.

An introductory curriculum module provides a broad overview of the content covered in the complete set of modules. Several of the modules make use of a comparison format requiring students to complete Venn diagrams. Therefore, the package includes a lesson on designing Venn diagrams, and some team exercises to practice their use. The students will then make use of both the comparison format and teamwork skills in the other modules. The first draft of each of the following modules are nearing completion:

Global Warming Module: Background information regarding global warming and the greenhouse effect will be presented using an Internet website. The students will be responsible for the information presented by completing a set of student worksheets that are written specifically for the website.

Greenhouse Laboratory Module: A laboratory module, utilizing a terrarium, will synthesize the information taught in the Global Warming Module in a hands-on, practical manner. The students

investigate what causes temperature shifts under different conditions. The students design their terrariums, collect the temperature data, and present their findings.

Climate In Your City Activity: This module introduces the students to the idea of collecting data and analyzing it from internet sources. It will use National Aeronautics and Space Administration's (NASA) climate indicator to investigate trends in temperature and climate factors for the US, selected world cities, and the student's own hometown. The teachers are provided with a preview lesson and overheads to prepare the students understanding of how the climate index works and how to read the graphs and maps.

Willow as a Renewable Energy Resource Module: This module presents the core information regarding willow biomass crops as a renewable resource. It remains reader friendly and reviews the knowledge presented in the global warming and green house effect activities. Building on this knowledge, it explains the benefits of using willow biomass as a renewable energy resource, highlighting the fact that willow biomass energy is CO_2 neutral and has a positive energy out to energy in ratio.

CO_2 Closed Loop Laboratory Module: This laboratory uses coins to demonstrate the concept of a closed loop cycle, helping present the CO_2 cycle and energy balances associated with willow biomass crops. The laboratory explores the different energy out to energy in ratios for other fuel sources such as gas, oil, and coal in comparison to the ratio for willow biomass.

Density Laboratory Module: Three exercises are provided to help explain the concept of density. The first two exercises present the concept of density and require the students to determine the density of three different items. The exercises go through the techniques needed to calculate the density of an irregular shaped object. These concepts are then applied to finding the density of willow wood for the third exercise. Oven dried samples of different willow clones will be provided for this laboratory. Students are then required to use the results to assess what volume of willow biomass is required to produce a given amount of energy.

Presentations and Conferences

During the past year, staff from SUNY-ESF and CNY RC&D have cooperated to educate a wide range of audiences about the willow biomass program goals and current research and development activities. Target audiences have been diverse, including elementary and high school students, university students, agriculture and natural resources professionals, environmental advocacy groups, landowners, policy makers and scientists. Communication techniques have included one on one conversations, displays, field tours and presentations to groups of various size.

First Quarter

- In February, staff from CNY RC&D presented a Willow Bioenergy display at the Farming for the Future Conference sponsored by the Pennsylvania Association for Sustainable Agriculture in State College, PA. A similar display and the Step Planter were presented at the NY Farm Show, Syracuse, NY, which is the largest indoor agricultural show in NY. Space at the show was provided by New York State Electric and Gas Corporation. Over 100 people stopped by the display. Twenty of them added their names to the Willow Biomass Newsletter mailing list. The presence of the Step Planter (Fig. 1) as part of the display contributed to the high level of interest in the display.

Figure 1. The Step Planter on display at the NY Farm Show in February 2001.

- On March 20, CNY RC&D staff conducted a hands-on demonstration for two kindergarten classes at the Science Fair in the Unadilla Valley School District. Willow cuttings and grass seed were planted to show that plants can be grown from both cuttings and seeds.

Second Quarter

- In April, Dr. Edward Neuhauser from Niagara Mohawk Power Corporation made a presentation on renewable energy at SUNY-ESF as part of the College's week long Earth Day activities. Willow biomass was highlighted as a feasible source of renewable energy for the Northeast.

- On April 21, CNY RC&D presented a Willow Bioenergy Display and slide show at the Sustainable Energy Fair, Canton, NY. The same presentation was made the next day at the Earth Day Celebration at the Rogers Environmental Education Center, Sherburne, NY.

- CNY RC&D staff made a slide presentation on the willow biomass project at the Chenango County Bird Club on May 9 in Sherburne, NY. Approximately 20 people attended. Data collected by the Cornell Laboratory of Ornithology on nesting species and nest density in willow biomass crops was highlighted.

- CNY RC&D staff distributed the Cooperative Business Structure Report to participating landowners and discussions with six of them were conducted May 29-30. The report details the potential for cooperatively owned equipment as an avenue to develop a willow biomass enterprise. The general consensus among the landowners interviewed is that it is too early in the development of the willow enterprise for them to consider forming a grower's cooperative. The delays of the emission tests at the Dunkirk Steam Station in western NY have fueled landowners apprehension regarding a future bioenergy market for willow biomass. However, most landowners indicated that a cooperative would be a good business model to consider once a market is more firmly in place.

- Also in May, SUNY-ESF staff made a presentation about the willow biomass program and conducted a field tour of research and demonstration plots at Tully, NY for a group of high school teachers as part of a three day symposium on Teaching, Learning and the Urban Environment held at SUNY-ESF. The participants were very pleased with the program and gave it a score of 4.7 out of 5.0.

- On May 30, CNY RC&D personnel presented "Growing Electricity" at the Chautauqua County Conservation Field Days in Bemus Point, NY. Approximately 160 students and 14 teachers and chaperones attended.

Third Quarter

- A paper titled "Predicting within-family variability in juvenile height growth of *Salix* based upon similarity among parental AFLP fingerprints" (see full citation in the Papers and Reports section) was presented at the Quadrennial Joint Annual Meetings of the American Society of Plant Biologists and the Canadian Society of Plant Physiologists, Providence, RI, July 21-25, 2001. A poster titled "The effects of inbreeding on plant growth in second-generation families of *Salix eriocephala*" was presented at the same conference.

- An informational display on the Willow Biomass Program was set up at the Empire Farm Days in Seneca Falls, NY (August 7-9). The Step Planter was included as part of the display and

generated a great deal of participant interest. The Empire Farm Days is the largest outdoor agricultural show in NY State.

- CNY RC&D personnel presented an overview of the willow project at a Woods Walk in Chautauqua County, which was part of a Master Forest Owners Refresher Course (August 11). The Woods Walk was conducted on property at Gerry, NY (Brown) that includes an eight ha field planted with willow and poplar biomass crops.

- On August 13-14, SUNY-ESF hosted The Northeast Forest Soils Conference. As part of the conference, research on willow biomass was highlighted. A field trip included stops at the willow plantings at the SUNY-ESF Genetics Research Field Station in Tully, a demonstration planting in Canastota and a phytoremediation site in Utica. Over 60 people participated in the field tours.

- In September, staff from SUNY-ESF gave a field tour at the Canastota site followed by a presentation to local landowners and staff from the Madison County (NY) Planning Department. This was followed by a meeting to discuss ideas on growing willow biomass crops on muck soils. There are large areas of muck soils in the region that are no longer used for vegetable production and landowners are looking for alternative crops to grow. Several fields in Canastota were visited and inspected. Sites with different depths of organic material over marl were selected as potential locations for two one-ha clone-site trials.

- CNY RC&D personnel gave a presentation about the Willow Biomass Project at the Catskill Forestry Associations Annual Meeting (September 15).

- CNY RC&D staff made presentations at the Cortland Conservation Field Days (September 20 and 21) to approximately 350 students and 35 teachers and chaperones.

- Staff from SUNY-ESF presented a seminar titled "Genetic Improvement of Willows: Integrating Traditional Breeding and Biotechnology" to the Forest Biotechnology class at SUNY-ESF

- SUNY-ESF staff presented "Willow Bioenergy Crops for Greenhouse Gas Reductions by Co-Firing" at the Environmental Monitoring, Evaluation and Protection in New York: Linking Science and Policy conference in Albany, NY (September 24-25).

- Because of the terrorist attacks of September 11th, the Biomass of Americas Conference at Orlando, FL and the Society of American Foresters National Meeting at Denver, CO were cancelled. Five different poster and paper presentations on the Willow Biomass Program were scheduled for these meetings.

Fourth Quarter

- CNY RC&D personnel had a display on the Willow Biomass Program at the Northeast Agroforestry and Carbon Conference held in Binghamton (Oct. 2-4). SUNY-ESF staff gave a presentation titled "Willow Biomass Crops: A Carbon Neutral Feedstock for Bioproducts and Bioenergy" and presented two posters, "Developing a living willow snowfence program for New York State" and "Growing willow biomass crops on conservation reserve program (CRP) land in New York State: An economic assessment".

- CNY RC&D staff made a presentation on the Willow Biomass Project at the NY Association of Conservation Districts Annual Meeting at Buffalo, NY (October 29). Sixteen people attended.

- CNY RC&D staff participated in the Green Energy panel discussion on biomass in NY to promote willow as a source of environmentally friendly energy. Twenty-five people attended this event.

- CNY RC&D personnel gave a presentation on the Willow Biomass Program at the Agri-Energy Conference in State College, PA (November 12). Over 100 people attended the conference, which was hosted by West Penn Power Sustainable Energy Fund.

- CNY RC&D staff spoke about the Willow Biomass Project as part of the Slippery Rock University's Seminar Series and made a presentation to a graduate class in Sustainable Ecology. CNY RC&D staff toured the Macoskey Farm on campus to discuss possible uses for willow. The graduate housing is heated with wood and has a gray water system and composting toilet that could be utilized in a closed loop system with willow biomass crops. There is also a potential for the use of willow for soil phytoremediation and living snowfence projects at Slippery Rock.

- Staff from SUNY-ESF and Siemens presented a proposal to SUNY Cobleskill regarding the development of a biomass-fired combined heat and electric power facility for their campus. Willow would make up a portion of the biomass supply for the plant and various phases of the willow project could be integrated into components of the SUNY Cobleskill curriculum.

- A presentation and field tour (Fig. 2) of the research and demonstration plots was given to the SUNY-ESF Silviculture class (FOR 534). A highlight of the tour was a demonstration of the recently delivered Bender willow harvester.

- SUNY-ESF and Siemens staff made a presentation to the Argyle, NY school board about the potential for a biomass fired combined heat and power facility at their school. Interest was

expressed in exploring the idea further and a committee was set up by the school board.

- SUNY-ESF published the Proceedings of the Third Biennial Conference of the Short-Rotation Woody Crops Operations Working Group. The proceedings include papers on various aspects of short-rotation woody crops in the United States, Europe and Canada. The report is available online at www.esf.edu/willow/.

Figure 2. Tim Volk leads a SUNY-ESF Silviculture class on a tour of the Tully, NY willow biomass research and demonstration plots. (Photo by R. Nissen)

Papers, conferences and reports

Interest in willow bioenergy crops and their potential for producing multiple environmental and rural development benefits has resulted in continued requests for information and presentations at various conferences and workshops. Over the past year, the following papers and reports, and posters were presented and/or published:

Refereed papers

- Kopp R.F., L.B. Smart, C.A. Maynard, J.G. Isebrands, G.A. Tuskan, and L.P. Abrahamson. 2001. The development of improved willow clones for eastern North America. The Forestry

Chronicle 77(2):287-292.

- Kopp R.F., L.B. Smart, C.A. Maynard, G.A. Tuskan and L.P. Abrahamson. 2001. Predicting within-family variability in juvenile height growth of *Salix* based upon similarity among parental AFLP fingerprints. Accepted for publication in Theoretical and Applied Genetics.

- Kopp R.F., C.A. Maynard, P. Rocha de Niella, L.B. Smart and L.P. Abrahamson. 2001. Collection and storage of pollen from *Salix* (Salicaceae). Submitted for publication in the American Journal of Botany.

- Kopp, R.F., L.P. Abrahamson, E.H. White, T.A. Volk, C.A. Nowak, and R.C. Fillhart. 2001. Willow biomass production during ten successive annual harvests. Biomass and Bioenergy. 20:1-7.

- Tharakan, P.J., D.J. Robison, L.P. Abrahamson and C.A. Nowak. 2001. Multivariate approach for integrated evaluation of clonal biomass production potential. Biomass and Bioenergy. 21:237-247.

Reports

- Kopp, R.F., L.B. Smart, C.A. Maynard, T.A. Volk, L.P. Abrahamson, and E.H. White. 2001. Genetic Improvements of Willows. Final Program Report. Prepared for the United States Department of Energy under cooperative agreement No. DE-FC36-96GO10132. Short-Rotation Woody Crops Program at SUNY-ESF, Syracuse, NY. 101 pp.

- Neuhauser, E. and S. Edick. 2001. Cooperative Business Structure Report. Technical report prepared for the United States Department of Energy under cooperative agreement No. DE-FC36-96GO10132. Niagara Mohawk Power Corporation, Syracuse, NY. 18 pp.

- Nordman, E.E., R.F. Kopp, D.J. Robison, T.A. Volk, L.P. Abrahamson, and E.H. White. 2001. Integrated Pest Management in Willow Biomass Crops. Final program report prepared for the United States Department of Energy under cooperative agreement No. DE-FC36-96GO10132. Short-Rotation Woody Crops Program at SUNY-ESF, Syracuse, NY. 66 pp.

- Tharakan, P.J., C.A. Nowak, T.A. Volk, S.P. Phillipon, L.P. Abrahamson, and E.H. White. 2001. Clone-Site Testing and Selections for Scale-Up Plantings. Interim Program Report. Prepared for the United States Department of Energy under cooperative agreement No. DE-FC36-96GO10132. Short-Rotation Woody Crops Program at SUNY-ESF, Syracuse, NY. 46 pp.

- Volk, T.A., L.P. Abrahamson and E.H. White. 2001. Alternate Methods of Site Preparation for Short-Rotation Willow and Poplar Biomass Crops. Interim report prepared for the United States Department of Energy under cooperative agreement No. DE-FC36-96GO10132. Short-Rotation Woody Crops Program at SUNY-ESF, Syracuse, NY. 40 pp.

- Volk, T.A., L.P. Abrahamson and E.H. White. 2001. Root Dynamics in Willow Biomass Crops. Interim report prepared for the United States Department of Energy under cooperative agreement No. DE-FC36-96GO10132. Short-Rotation Woody Crops Program at SUNY-ESF,

Syracuse, NY. 23 pp.

Conference papers and presentations

- Kiernan, B.D., T.A. Volk, J.A. Dickerson, A. Barber, D. Barber and S. Butts. 2001. Developing a living willow snowfence program for New York State. Northeast Agroforestry and Carbon Conference, Binghamton, NY Oct 2-4.

- Kopp R.F., L.B. Smart, C.A. Maynard, G.A. Tuskan and L.P. Abrahamson. 2001. Predicting within-family variability in juvenile height growth of *Salix* based upon similarity among parental AFLP fingerprints. Quadrennial Joint Annual Meetings of the American Society of Plant Biologists and the Canadian Society of Plant Physiologists, Providence, RI, July 21-25, 2001.

- Kopp R.F., L.B. Smart, C.A. Maynard, G.A. Tuskan and L.P. Abrahamson. 2001. Predicting within-family variability in juvenile height growth of *Salix* based upon similarity among parental AFLP fingerprints. Abstract of a paper accepted for presentation at the 26th Biennial Southern Forest Tree Improvement Conference in Athens, GA, June 26-28, 2001.

- Phillips I.S., R.F. Kopp, C.A. Maynard, L.P. Abrahamson, and L.B. Smart. 2001. The effects of inbreeding on plant growth in second-generation families of *Salix eriocephala.* Quadrennial Joint Annual Meetings of the American Society of Plant Biologists and the Canadian Society of Plant Physiologists, Providence, RI, July 21-25, 2001.

- Tharakan, P.J., T.A. Volk, C.L. Lindsey, S. Edick, J. Dickerson, P. Ray and L.P. Abrahamson. 2001. Growing willow biomass crops on conservation reserve program (CRP) land in New York State: An economic assessment. Northeast Agroforestry and Carbon Conference, Binghamton, NY Oct 2-4.

- Volk, T.A., L.P. Abrahamson, E.H. White. 2001. Willow Biomass Crops: A Carbon Neutral Feedstock for Bioproducts and Bioenergy. Northeast Agroforestry and Carbon Conference, Binghamton, NY Oct 2-4.

- Volk, T.A., L.P. Abrahamson and E.H. White. 2001. The status of the Salix Consortium's willow biomass program. In Volk, T.A., J. Ballard and L.P. Abrahamson (Compilers), Proceedings of the Third Biennial Short-Rotation Woody Crops Operations Working Group Conference, Syracuse, NY October 10-13, SUNY-ESF, Syracuse, NY. pp 25-34.

- White, E.H., L.P. Abrahamson, T.A. Volk. 2001. Willow Bioenergy Crops for Greenhouse Gas Reductions by Co-Firing. Environmental Monitoring, Evaluation and Protection in New York: Linking Science and Policy conference, Albany, NY September 24-25.

Conservation Reserve Program

On March 21, 2001, the US Department of Agriculture announced approval of a pilot project to grow willow biomass crops that will be used for bioenergy on Conservation Reserve Program (CRP) land in central and western New York. The New York program was one of four approved in the country. The

project, initiated by CNY RC&D, SUNY-ESF and Antares, Inc. provides for the establishment of 6,000 ha of willow biomass crops interspersed with herbaceous cover such as switchgrass and/or other native and introduced grasses. The crop's perennial nature, rapid growth, diffuse root systems, and high density of plantings makes them an ideal crop to reduce soil erosion and non-point source pollution, improve water quality and enhance wildlife resources. Under this program, landowners would be eligible for support from the USDA for up to 50% of the establishment cost of the crop as well as an annual payment for the land in the program. This will be a significant economic benefit for landowners considering growing willow biomass crops and a major stimulus for the development of a willow biomass industry in New York.

CNY RC&D staff spoke with the Pennsylvania Switchgrass Group about their CRP Pilot Project and potential cooperation on requesting changes in the restrictions from Farm Services Agency in Washington, D.C.

Enterprise Development

About 18 dry tonnes of willow biomass from a clone-site trial in Burlington and from Resource Efficient Agricultural Production-Canada (REAP-Canada) at Ste. Anne de Bellevue, Quebec were transported to the McNeil Station in Burlington, VT. The biomass was tested as a feedstock for the gasifier located at the plant. The McNeil gasifier is a joint project of DOE and Future Energy Research Corp. (FERCO) of Atlanta, Ga. Data from the trial are being processed and will be available in the near future.

FORECON received a grant through the New York State Energy Research & Development Authority (NYSERDA) Innovation in Agriculture Award for market research in willow biomass crops. Several businesses in western NY have expressed an interest in willow, including a wood pellet manufacturer interested in converting willow into pellets and sawmills interested in utilizing willow for heat production. SUNY-ESF and CNY RC&D are cooperating with FORECON on this project.

An updated Field Activity Data Sheet was created and distributed to FORECON to improve the accuracy and detail of the data collected during field operations. It was used during the final set of coppicing operations this winter and will be used for all field operations in the future. The additional information collected will assist in modeling the economics of the system as well as providing useful data for a Life Cycle Analysis that is underway as a joint project between the University of Michigan, SUNY-ESF, and the National Renewable Energy Laboratory.

CNY RC&D and SUNY-ESF staff provided information to personnel at the Colgate University Heating Plant on the fuel characteristics of willow. They then met with the heating plant crew to discuss using willow biomass in their wood-fired boiler. It appears that willow biomass chips are well suited to

their needs. The eight ha demonstration planting at Canastota, planted in 1998, is scheduled to be harvested this winter and Colgate University, located 40 km away, is a potential market for this material. Colgate staff will be invited to observe harvesting when it occurs in Canastota, and, if they are satisfied with the quality of the chips, arrangements will be made to deliver a load of the material to the heating plant for test burns.

The Bender harvester (Fig. 3), which will be used for harvesting about 40 ha of willow biomass crops in central and western New York this winter, was delivered to SUNY-ESF from Sweden in early October. This version of the Bender has several improvements over the previous version including new feed and chipping mechanisms. A GPS data collection system will be configured for the harvester by staff from Cornell University Department of Biological and Agricultural Engineering to assist in evaluating its efficiency. Mats Wilstrand from Sweden visited SUNY-ESF to provide training on the operation and maintenance of the new Bender harvester for staff from SUNY-ESF and Cornell University. All of the initial problems matching the Bender to the New Holland TV-140 tractor were resolved. Cornell University staff built and installed a discharge chute so that chips could be blown directly into a dump wagon being pulled by the tractor. Later in the month, staff from FORECON were trained by SUNY-

Figure 3. The Bender harvesting willow biomass crops on three-year-old demonstration plots in Tully, NY. (Photo by R. Nissen).

ESF and Cornell University staff on the operation and maintenance of the Bender. About one ha of three-year-old willow and poplar was harvested at Tully during the training. Another ha was harvested in order to calibrate the load cells on the dump wagon weight scales and fuel consumption gauge on the tractor.

While most of the problems with the new Bender harvester have been resolved, a remaining difficulty is the number of long twigs that pass through the system unchipped, especially when smaller stature willow is harvested. Several modifications to the harvester were made, but the chips are still not meeting the desired specifications. A new screw for the chipper is being manufactured in Sweden that should greatly reduce this problem. Harvesting of three-year-old willow plots in central and western New York has been put on hold until the new chipping screw is obtained, installed in the harvester and tested.

Personnel from Alfred University in Alfred, NY and SUNY-ESF met to discuss utilizing willow biomass in a small-scale gasifier developed by staff at Alfred University. SUNY-ESF agreed to provide several types of chipped willow biomass (i.e. freshly harvested with leaves, freshly harvested without leaves, dried, etc.) for initial modeling efforts. Funding is being sought to conduct detailed production scale tests in the gasifier.

In the past year, there has been increased interest in the use of willow biomass as a feedstock in a biorefinery model where both bioproducts and bioenergy are produced. Samples have been provided for individuals developing a fungal pre-treatment (biopulping) to optimize the yield of both usable papermaking fiber (cellulose) and water-extractable xylan from willow. Xylan can be fabricated into high performance, biodegradable fibers, films and composites. These products represent biodegradable alternatives to petroleum-derived polyethylene and polystyrene. From an economic perspective, it was estimated that process improvements leading to efficient xylan extraction and utilization have the potential to improve the economic value of a tonne of willow biomass. About 125 kg of xylan (assuming 25% by weight of xylan and 50% recovery) could be recovered from each dry tonne of willow biomass. This would add $20 to the value of a tonne of willow biomass.

International Interest

A tour of willow research and demonstration areas at Lafayette and Tully was provided for a visiting scientist from the Pakistan Forest Department. The short-rotation coppice system is of interest because of potential applications in Pakistan.

Li Ruizhi, Associate Professor from Shandong Provincial Forestry Department, Shandong Province, China joined the SUNY-ESF Short-Rotation Woody Crops Program as a visiting scholar. Li is observing willow biomass programs, evaluating the recently received Chinese and Japanese willow clones and working with Drs. Smart and Kopp on developing future breeding plans involving Chinese willow clones.

A staff member from the Department of Forestry in Israel visited SUNY-ESF to learn more about the Short-Rotation Woody Crops Program. Time was spent looking at research and demonstration plots in Tully and discussing potential applications for the system to projects being developed in Central Asia.

Lawrence Smart and Lawrence Abrahamson visited the Jiangsu Forestry Academy in China during December 2001 to interact with genetic researchers and discuss further cooperation between the two genetic improvement programs. Drs. Smart and Abrahamson presented four talks each on the willow biomass crop system and willow breeding in the United States. Presentations were made at the Beijing Forestry University and the Chinese Forestry Academy in Beijing, and the Jiangsu Forestry Academy and the Nanjing Forestry University in Nanjing. Future visits between SUNY-ESF and Jiangsu Forestry Academy researchers were discussed as well as possible exchange of visiting scholars between the two schools.

SUNY-ESF staff also made a presentation on the Willow Biomass Project to two visitors from the Ishikawajima-Harima Heavy Industries Co., located in Japan.

WILLOW DEMONSTRATION FARMS ACTIVITIES

Alternative Methods of Site Preparation for Willow Crops

The alternative site preparation study at the Lafayette demonstration farm was harvested during the winter of 2000/01. The trial was planted in 1997 and coppiced during the winter of 1997/98. Results from this trial are summarized below in the Executive Summary from the interim report on this study. The full report can be found at the Short-Rotation Woody Crops' web site, www.esf.edu/willow.

Executive summary

The proper application of effective site preparation techniques is essential to the biological and economic success of short-rotation willow and poplar biomass crops. Failure to control weeds during site preparation and through the establishment year causes decreased survival and production, frequently resulting in the failure of the crop. The standard technique is fall tillage site preparation, which includes a late summer application of post-emergence herbicides, followed by plowing and disking before winter. A final cultivation is conducted the following spring, immediately prior to planting, which is followed immediately with the application of a pre-emergent herbicide.

While the fall tillage site preparation approach is effective for establishing willow and poplar biomass crops, it creates the potential for significant soil erosion. If conducted properly, the fall tillage technique results in limited vegetation cover from the time of plowing until the canopy begins to close in the summer of the second year of growth. Under these conditions soil erosion rates on sites with certain soil and topographic characteristics could exceed those recorded for annual agricultural crops. The majority of land that will initially become available for willow and poplar biomass crop production in the northeastern and midwestern United States is lower quality agricultural land that has characteristics

that make it prone to soil erosion. One study estimated that about 130 MT ha^{-1} of soil were lost during the establishment year in a hybrid poplar trial on a Mardin silt loam soil with a 13% slope. The soil erosion issue is important because of the increasing concern surrounding non-point source pollution from agriculture lands, the detrimental effect it could have on long-term sustainability of the production system, and the damaging impact it could have on the public perception of willow and poplar biomass crops.

A variety of conservation tillage and other ground cover management techniques have been developed to address soil erosion concerns without adversely effecting crop yields for annual agriculture and orchard systems. Some of the more successful approaches include no-till and strip tillage. In addition, the use of cover crops and altering the timing of different tillage operations has been shown to reduce soil erosion. However, little work has been done on establishing short-rotation woody crops (SRWC) using any conversation tillage and/or alternative ground cover management techniques especially for systems with densities greater than 10,000 plants ha^{-1}.

This study assessed the impact of six different methods of site preparation on survival and aboveground biomass production of high density, short-rotation willow and poplar biomass crops. The six treatments studied were 1) the standard fall tillage system, 2) fall tillage followed by the establishment of a winter rye cover crop, 3) no-till, 4) strip tillage applied in the spring, 5) spring tillage, and 6) no weed control. The study site, located in Lafayette, NY, is a Honeoye silt loam soil with 2- 8% slope. It had been out of corn production for two years and was dominated by a mixture of perennial weeds. Following the application of the different treatments, plots were hand planted in the spring of 1997 with either willow (SV1 – *Salix dasyclados*) or hybrid poplar (NM6 – *Populus nigra* x *maximowiczii*) at a density of 14,376 plants ha^{-1}. The plants were coppiced during the dormant season after the establishment year. First rotation harvest occurred three years after coppicing.

Survival was assessed at the end of each growing season. After the establishment year and at the end of the end of the first three-year rotation aboveground biomass production was measured directly by cutting the plants. Aboveground biomass production was estimated in the first and second year of coppice growth using stem diameter measurements and allometric equations that had been developed previously.

Establishment year (1997) survival for the poplar was greater than 96% in five of the six treatments and 84% in the no weed control treatment. Poplar survival decreased by less than 7% in any treatment between the establishment year (1997) and the end of the first three-year rotation in 2000. Only the no weed control treatment had a significant reduction in survival. Willow survival at the end of the establishment year was good, ranging from 84 to 95%. By the end of the first rotation willow survival had dropped significantly in the no-till, no weed control and strip tillage treatments resulting in 30%, 55%, and 70% survival, respectively. Survival for the spring tillage, fall, and cover crop treatments at the end of the first rotation was 94%, 90%, and 85%, respectively.

At the end of the first three-year rotation, aboveground biomass production for poplar clone NM6 in the four best treatments (strip tillage, fall tillage, spring tillage, and cover crop) was 36.4 to 37.6 odt ha^{-1}. These are the highest reported first-rotation yields of NM6 grown at this density in the northeastern United States. Not controlling weeds reduced the poplar yield by 23.1 odt ha^{-1}. Treatments that included tillage increased production by 8.4 odt ha^{-1} compared to the no-till plots.

At the end of the first three-year rotation willow clone SV1 aboveground biomass ranged from 0.4 odt ha^{-1} in the no-till and no weed control plots to 24.0 odt ha^{-1} in the

spring tillage plots. The best production at this site was at the low end of the range of other trials in the northeastern United States where willow clone SV1 has been grown at this density. Biomass production was 13.2 odt ha^{-1} greater in the weed control treatments compared to the no weed control treatment. Treatments that included tillage produced 16.9 odt ha^{-1} more aboveground biomass than the no-till treatment. At the end of the first rotation the cover crop and spring tillage treatments produced 7.6 odt ha^{-1} and 10.0 odt ha^{-1} more biomass than the fall tillage treatment.

First rotation results from this trial indicate that the spring tillage, cover crop, or strip tillage treatments are viable alternatives to the currently standard fall tillage treatment for NM6 on similar sites. All of these treatments produced over 36 odt ha^{-1} in the first rotation. These alternative site preparation approaches should reduce erosion potential on many sites by providing vegetative cover on the soil over a longer period compared to the standard fall tillage approach. Alternative site preparation treatments often produce different results depending on the field history, soil characteristics and weather conditions. Caution should be used when transferring these results to sites with field histories and soil characteristics that are different from the one used in this study.

For willow clone SV1 the spring tillage and cover crop treatments produced the most aboveground biomass followed by the fall tillage treatment. These approaches may be viable alternatives to the standard fall tillage approach to site preparation. However, first rotation production for the spring tillage and cover crop treatments was only 24 and 21 odt ha^{-1} respectively. These values are at the low end of the range of values that have been reported for other trials in central NY using SV1 grown at a similar density. It is unclear at this point why the fall tillage treatment, which is currently the standard practice, was less successful than the spring tillage and cover crop treatment. Additional analysis of soil and foliar nutrient characteristics and levels of weed competition may help explain some of the differences between the treatments and the low overall production of SV1 in the first rotation. As with the poplar results, caution should be used when transferring these results to sites with field histories and soil characteristics that are different from the one used in this study.

In the spring of 2001, 48 of the 64 plots in the alternative site preparation study at Lafayette were split in half to assess the impact of increased weed control and N fertilizer on second rotation yields. One half of each plot, randomly selected, was mechanically weeded with a tractor mounted rototiller, sprayed with simazine (2.2 kg ai ha^{-1}), and treated with slow-release sulfur-coated urea (39-0-0) at 224 kg ha^{-1} N fertilizer. The other half of each plot was only treated with 112 kg ha^{-1} of the fertilizer. Weed growth was assessed in July by harvesting all weeds from four 0.09 m^2 quadrats in each subplot. After leaf fall, stem diameters at 30 cm of all stool stems were measured and the maximum stem height of each stool was recorded. The objective of this field activity is to determine if it is worth expending additional time and resources on areas with poor yields and/or survival in the first rotation. Results should be available in the latter half of 2002.

Results from the alternative site preparation study indicated that a winter cover crop treatment produced yields comparable to those from site with full fall site preparation. However, questions remain about how to manage the crop in the spring before planting. The objective of a new rye cover crop trial at the

SUNY-ESF Research Station in Tully, NY is to assess the impact that different winter rye cover crop management strategies have on willow and poplar establishment and growth. Site preparations began on this site in 1999, including seeding winter rye in September at a rate of 56 kg ha^{-1}. Site preparations were continued in the spring of 2000. The following treatments, with four replications each, were completed:

1. Spray the cover crop with glyphosate (2.24 kg ai ha^{-1}) and disk in crop residue.
2. Spray the cover crop with glyphosate (2.24 kg ai ha^{-1}) and leave residue standing on site.
3. Mow with a sickle bar mower immediately before planting.

Two clones, SV1 and NM6, were planted with the Step Planter. Oxyfloufen (Goal 2XL) and simazine (Princep) preemergent herbicides were applied at the rates of 1.12 and 2.24 kg ai ha^{-1}, respectively. The plants were coppiced in the winter of 2000/01 with a sickle bar mower. This site was fertilized in the spring of 2001 using slow-release sulfur-coated urea (39-0-0), applied at 120 kg N ha^{-1}. Over the course of the growing season the percent weed cover, by species, was measured in each plot. Heights of the willow and poplar were measured every two or three weeks. All plots were rototilled to reduce weed competition. Regular monitoring of the cover crop trial included weekly measurements of soil moisture at 0–15 cm depths and weekly assessments of rye residue and weed cover in all the plots. Foliage samples for nutrient analyses were collected. Measurements of maximum stool stem heights and individual stem diameters were completed after leaf fall for one willow and one poplar clone that are one-year-old aboveground on two-year-old root systems.

Willow Coppicing Study

The coppicing study was established in 1997 on willow demonstration farms in Canastota, Tully, and Wolcott, NY to examine the effect on yield of coppicing vs. not coppicing willow and poplar clones after their first year of growth. The study is now at the end of its fourth growing season with plants that are three-years-old aboveground on four-year-old root systems (coppiced after the first growing season) and four-years-old aboveground on four-year-old root systems (not coppiced). Maximum height and stem diameter measurements were collected during the winter of 2000/01 and at the end of the 2001 growing season from over 2,800 stools on 168 plots. During the winter of 2000/01, samples from each of four (Wolcott), five (Canastota) or six (Tully) clones were collected to develop allometric equations to estimate biomass while minimizing destructive sampling. All plots will be harvested in the winter of 2001/02. Yield data will be collected and results will be published in appropriate reports and papers.

Willow Demonstration Farm Operations

A 3.5 ha field was planted with willow in Canastota, NY in June 2001. Side by side assessments of planting rates for the Step and the Fröebbesta planters were made by staff from the Department of

Agricultural and Biological Engineering at Cornell University using GPS equipment. The trial will be monitored to assess the relative efficiency of the two types of planters and to determine if there are differences in survival and growth rates attributable to the planting mechanism. Following planting the site was capped with a mixture of simazine (2.2 kg ai ha^{-1}) and oxyfluorfen (1.1 kg ai ha^{-1}). The site was later spot sprayed with fluazifop-p-butyl (Fusilade at 0.5% solution) to control grass weed. Other weeds were not a problem on this site.

SUNY-ESF personnel collected foliage samples for nutrient analyses at the demonstration plantings at Canastota, Wolcott, Lafayette and Tully, NY. These sites are due to be harvested during winter 2001/02. The Canastota and Wolcott sites were planted in 1998, Lafayette in 1997 and King Ferry in 1996. This will be the first harvest on these sites. Two areas in Tully will be harvested in the winter of 2001/02. The first area was planted in 1995 and was harvested once in December 1998. The second area was planted in 1997 and has not been harvested previously.

Riparian Buffers

Over the past year there have been three meetings with staff from the Onondaga County Soil and Water Conservation District (SWCD), New York State Department of Environmental Conservation (NYSDEC), US Fish and Wildlife Service (USFWS), SUNY-ESF, United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS), and the landowner to discuss the establishment of a multi-species riparian buffer along Spafford Creek at the south end of Otisco Lake. The landowner removed woody vegetation along the stream in the summer of 1998 to facilitate his farming operations. This action resulted in increased run-off and erosion. The new buffer will be designed based on previous research and demonstration projects and discussions with participating agencies and the landowner. The site will become a focal point for demonstration and education efforts.

The Onondaga County SWCD completed a survey of the stream and begun work on the first 300 m of the stream. The design for the remainder of the riparian buffer of Spafford Creek will be completed in the spring of 2002 and installation on the remaining 900 m should be initiated if all participating agencies and the landowner approve the design. No willow was planted in 2001 because work did not begin until late summer, past the time of establishment.

SUNY-ESF personnel met with personnel from the USDA offices in Jefferson County to discuss potential research projects that would include willow in multi-species riparian buffer strips. There are ongoing efforts to reduce agriculture runoff in this county, with much of the effort currently focused on the Sandy Creek watershed. As part of this effort, multi-species riparian buffer strips will be planted in the Sandy Creek watershed during spring 2002. Eight landowners are currently signed up to establish riparian buffer strips.on this land

Related Efforts

Since the mid 1980s a mixture of private organizations and state and federal agencies have been involved in supporting research and development of willow biomass crops for bioenergy and bioproducts. Private organizations have primarily been associated with utilities and consulting firms developing biomass energy applications and phytoremediation opportunities associated with willow. New York State Electric and Gas (NYSEG), Niagara Mohawk Power Corporation (NMPC), the Gas Research Institute (GRI), Electric Power Research Institute (EPRI), Wegmans Egg Farm Inc., ARM Inc., and E^3 Ventures are the main private organizations that have been involved. The federal Departments of Energy (USDOE), Agriculture (USDA), and the Environmental Protection Agency (USEPA) have all supported various components of an integrated willow biomass program at SUNY-ESF. The New York State Energy Research and Development Authority (NYSERDA) has been a consistent, long term supporter of willow biomass crop research and development. Other state agencies such as the Pennsylvania Department of Natural Resources, Delaware Department of Agriculture and the New Jersey Department of Environmental Conservation have been involved in examining the potential of willow biomass crops in their individual states. The wide ranging support from both private and public agencies has been instrumental in making New York a leader in this field.

The willow biomass program is made up of several well integrated components that are supported by different organizations. The success of the overall program is dependent on the synergy created by the individual parts. For example, the gains in yield and insect and pest resistance that are being realized from the willow genetics program, which has been mainly supported by USDOE, are essential to the development of a commercial willow biomass enterprise. Results from clone site trials and large scale harvesting operations on the demonstration farms, which are supported primarily by the USDA, provide essential information to guide selection of clones used in the breeding program. The related efforts summarized below are critical to the success and development of the program but were not supported directly by the USDA program. The primary agencies supporting each related effort are highlighted at the beginning of each section.

Living Willow Snowfences (leveraged support from USDA NRCS)

A meeting was held on January 22 with representatives from SUNY-ESF, NRCS, Cortland County SWCD, Cortland County Department of Transportation (DOT), New York State DOT, and Steve Butts, a local landowner with a seven-year-old willow snowfence. This was the second in a series of meetings to establish a living snowfence program using easily established, fast-growing shrub willows. The group identified specific requirements for further progress on the project, such as a summary of snowfence research and identification of areas where blowing snow is a problem.

As a result of these inter-agency efforts, a new living willow snowfence was established during May in South Cortland, NY (Fig. 4). About 115 m long, the snowfence was designed with two clones that

exhibit different morphology (i.e. density and height growth) to meet the objectives of the landowner. The snowfence was designed to protect the landowner's house and driveway, as well as ameliorate snow drifting onto the roadway.

A living willow snowfence was established in Cortland in 1993. The site is currently the project's primary demonstration and protocol development site. The 1993 Cortland site is being used to develop protocols for assessing snowfence density and snow depth patterns.

A presentation was made to the New York State Thruway Authority on the potential use of willow along this highway as part of a right-of-way management plan. Willow can be utilized to reduce headlight glare and as a fast-growing living snowfence. These plantings would help to reduce accidents and costs associated with snow removal.

Figure 4. Site preparation at the site of the new living willow snowfence in South Cortland, NY.

Western NY Operations (major support from USDOE (NREL and ORNL) and NYSERDA)

During the winter of 2000/01, FORECON and independent grower Denny Barmore completed coppicing operations on the demonstration plantings near Westfield (70 ha) and Gerry, NY (10 ha), on sites planted in spring 2000. Frost heaving was a problem in some areas. It is suspected that the problem occurred when the snow cover was lost on parts of the fields during a mid-winter thaw. During the spring of 2001, these sites were interplanted. Hand interplanting was done on areas with survival between 50 and 80%. Areas with survival of less than 50% were interplanted with the Fröebbesta

planter. Of 70 ha planted in the Westfield area last year, approximately 60 ha were interplanted or had survival rates high enough that interplanting was not warranted. The remainder was not completed because of limitations in the supply of cuttings and budget constraints. Spraying of fluazifop-p-butyl (Fusilade) at 1.12-1.68 kg ai ha^{-1} was used in selected areas to control grasses.

Cultivation and fertilization of the large-scale demonstration areas near Westfield and Gerry, NY were completed in spring 2001. Slow-release sulfur-coated urea (39-0-0) was applied at 120 kg N ha^{-1}. Weed control in the spring was good in the Westfield plantings. Weeds were a problem at the Gerry site, so the site was cultivated again later in the season. Growth of the willow and poplar is generally good despite the weeds and the trees are expected to out compete the weeds in most areas. However, in some areas, particularly where goldenrod (*Solidago* spp.) is abundant, weed competition is likely to impact survival and growth. Weeds continued to be a problem in some areas of the demonstration planting at Gerry. Ragweed (*Ambrosia artemisiifolia*) became a problem at the demonstration plantings in Westfield. In some areas, the ragweed was taller than the willow, creating competition for light. Deer browse was observed on clone SV1 on several sites at Westfield and Gerry. Browse damage was considered moderate. Little or no insect damage was observed in Westfield and Gerry sites. Rust (*Melampsora* spp.) was observed on S301 at the Gerry and Westfield (L. Knight and Hetrick Sr.) sites during a site inspection on June 13. Infection was considered light. Leaf rust has been observed on S301 each year in willow plantings in western NY. It was first observed on August 18, August 11, and July 7 during 1998, 1999 and 2000, respectively. These sites will be closely monitored to watch the development of the rust. Leaf rust was a problem with S301 last year and resulted in the mortality of many plants in a nearby site at Gerry (Brown), planted in 1999.

SUNY-ESF personnel collected survival data and foliage samples for nutrient analyses at the demonstration plantings at Sheridan (Smith and Hopkins) and Leon, NY (Klosinski). These demonstration areas were planted in 1998 and are scheduled for harvest during winter 2001-02. Survival for 2001 ranged from 67% (clone S301) to 75% (SV1) at the Leon site and 61% (SX67) to 72% (SV1) at the Sheridan site (Table 1). Mean survival was 73 and 66 percent at the Leon and Sheridan sites, respectively.

Staff from SUNY-ESF and FORECON visited the willow biomass demonstration areas in Leon and Sheridan that will be harvested in the winter of 2001-02. Harvesting and transportation logistics were discussed. Designs for both sites will allow harvested willow chips to be stored on site, at a separate location, or delivered immediately to the Dunkirk power plant.

Genetic Improvement of Willow (major support from USDOE (ORNL))

Second generation *Salix eriocephala* progeny that were produced during winter 2000 and planted in an observation trial at Syracuse, NY were coppiced. These seedlings were produced by mating full-sib,

half-sib, and unrelated F_1 parents. Harvested stems were collected for biomass determination. The objective of the study was to determine if inbreeding affects sylleptic branching, stem length, and stem biomass. Significant differences ($p<0.05$) in all three traits were detected among families, and progeny types (full-sib, half-sib, or unrelated second-generation mating). However, the effect of inbreeding on first-season growth was not as large as anticipated.

Table 1. Percent survival of willow and poplar clones at demonstration plantings in Sheridan and Leon, NY. Data collected 9/27/01.

	Survival (%)	
Clone	**Sheridan**	**Leon**
S25	64	73
SV1	72	75
S301	63	67
SX67	61	Not planted
SX61	69	Not planted
S646	Not planted	73
S546	Not planted	72
NM6	Not planted	69
Mean	**66**	**73**

Cuttings from 49 willow clones developed and tested at the Jiangsu Forestry Academy in Jiangsu, China, were obtained by SUNY-ESF. In exchange, *S. nigra* shoots were collected by cooperators in Florida, Kansas, and North Carolina, sent to SUNY-ESF, and forwarded to our Chinese cooperator, along with cuttings from 15 clones from the SUNY-ESF willow clone collection. Cuttings from 20 willow clones of *S. miyabeana* and *S. sachalinensis* were obtained from native stands near Sapporo, Japan. These 69 clones were established in a quarantined field planting at Tully, NY to be used in future controlled breeding when clones with desirable traits are identified and they are released from quarantine. Most of the genotypes from China have not been previously tested in New York. The few clones of these species that have been tested in the Northeast have grown exceptionally well.

S. alba pollen from six clones was obtained from a cooperator in the Czech Republic. The clones providing this pollen are used for stream-bank stabilization. The pollen will be used in controlled pollination with *S. alba* clones naturalized in central New York, to produce clones for use in riparian zones.

A research team composed of scientists from New Zealand and California collected open-pollinated willow seeds in the Pacific Northwest and sent them to SUNY-ESF. Species included in the seed collection were *S. lasiandra* and *S. lasiolepis*. Seeds were planted immediately upon receipt, and germination percentages were high for most of the half-sib families. *S. lasiandra* is closely related to *S. lucida*, a species of particular interest in the North-Central region of the United States, and attempts will be made to hybridize these species.

Controlled breeding completed using F_1 hybrid parents produced during 1999 showed that at least some progeny of all the hybrid families tested were fertile. All but one of the hybrid male clones tested yielded progeny that survived for six weeks or more and produced true leaves. Progeny containing germplasm from three different species were produced. Successful three-way hybrids include *S. purpurea* x (*sachalinensis* x *miyabeana*), *S. viminalis* x (*purpurea* x *miyabeana*), *S. viminalis* x (*sachalinensis* x *miyabeana*), and *S. sachalinensis* x (*purpurea* x *miyabeana*). These progeny were planted in the field during summer 2001. Flowers from hybrid females growing in the field will be observed to determine if they produce viable seeds resulting from successful open pollinations. This study confirms hybrid willows produced by controlled pollination during 1999 are fertile. Research is necessary to determine if native willow species are capable of intermating with the hybrids in the field. The one native species tested in this study, *S. eriocephala*, could not be successfully mated with hybrid clones.

A study containing some of the newest willow clones produced by controlled breeding and selection was planted at the SUNY-ESF Genetics Field Station at Tully, NY. The study includes 25 willow clones, 16 produced by controlled breeding, four selected from native stands in New York or Wisconsin, and five clones that have been planted in large-scale bioenergy demonstration farms. The purpose of this trial is to compare performance of the new bred and selected material with clones currently planted in bioenergy demonstration farms across the Northeast US, and to test the new willow clones for the first time in the North-Central US. Survival averaged 96%, with all but one clone having greater than 90% survival. Dr. Jud Isebrands (US Forest Service, North-Central Forest Experiment Station, Rhinelander, WI) planted a companion trial in Wisconsin in late June using the same clones.

Rooted cuttings of 106 willow clones, most of which were collected from native stands across the Northeast United States during summer 2000, were planted in a clone bank at the SUNY-ESF Genetics Field Station at Tully, NY. Species in the planting include *S. alba* (1 clone), *S. eriocephala* (57 clones), *S. lucida* (2 clones), *S. nigra* (23 clones, including material from Florida, Kansas and North Carolina) and *S. purpurea* (23 clones), with the number of ramets per clone ranging from 1 to 24. The original plan was to establish equally sized replicated blocks of every clone, but mortality of a large number of plants during winter 2000-2001, which was unequal across clones, made a replicated design impractical.

Clone-Site Trials (major support from USDOE and NYSERDA)

Clone-site trials in Jackson, NJ, Montour Preserve, PA, and the Wye River Research and Education Center, MD were coppiced. These sites were established during spring 2000. First year biomass data were collected at all three sites. Maximum height and stem diameter measurements, used to estimate standing biomass, were completed at the clone-site trials in Canastota, Sheridan and Wolcott, NY and

Dover, DE. These sites were planted in the spring of 1998 and coppiced during winter 1998/99. They are scheduled for harvesting during winter 2002/03.

The clone-site trial at Lafayette, NY was harvested. This site includes 14 willow and two poplar clones. It was planted in 1997 and coppiced during winter 1997/98. Stools in the 64 measurement plots were harvested and green weights were recorded. A sub-sample of three stems was taken from each plot to determine percent moisture of the material, which allows yield to be calculated in oven-dry tonnes.

Mechanical weed control was performed on clone-site trials at Jackson, NJ, Westfield, NY, Montour Preserve, PA and Wye River, MD. These sites were fertilized using slow-release sulfur-coated urea (39-0-0), applied at 120 kg N ha^{-1}. A third rotation clone-site trial at Massena, NY was likewise fertilized. That trial was planted in 1993 and was harvested in 1997 and 2000.

Planting Stock Production (major support from USDOE and NYSERDA)

SUNY-ESF personnel traveled to the NYSDEC Saratoga Tree Nursery (STN) to review progress on the production of 2001 willow and poplar cuttings and whips. Cutting and whip production at STN was completed by the end of February (Table 2). Details were collected on the harvesting and processing procedures at STN for the final nursery production report. The crew at STN reports that one of the biggest bottlenecks occurs in picking up and bundling the freshly cut stems in the field. In the winter 2000/01, they utilized a banding machine for the harvest operation for the first time, reducing handling time in the field by almost 60% compared to tying the bundles by hand. This machine utilizes polymer string (Tygertwine) and is typically used to tie the bundles of seedlings in the spring. The banding machine requires a generator for field use. The machine can be operated effectively while wearing gloves, so it has the added advantage of keeping the staff's hands warm during winter harvest. The machine used was designed for indoor use and did not work well in cold, wet weather. There are banding machines designed for outdoor use that should be more effective.

Application of Poultry Manure on Willow Biomass Crops (funding by NYSERDA and Wegman's Egg Farm Inc.)

SUNY-ESF conducted an experiment to compare willow chips with two other types of wood chips currently used by Wegman's as a carbon source for the composting of their chicken manure. Wegman's Egg Farm produces abundant amounts of chicken manure, much of which must be stabilized as compost. If willow chips prove effective as a carbon source for composting, willow grown on Wegman's land could reduce their reliance on outside sources of wood chips. Growing willow also provides opportunities for land application of compost and manure.

Table 2. Willow and poplar planting stock production figures for 2001 at SUNY-ESF and the Saratoga Tree Nursery (STN).

	SUNY-ESF		STN		
Clone	Cuttings	Whips	Cuttings	Whips	Totals
NM6	8,250	10,375	9,650	27,879	56,154
NM5	13,150	15,800	0	0	28,950
SV1	43,125	18,189	15,000	99,350	175,664
SX67	21,200	10,050	0	81,358	112,608
SX64	17,250	7,200	5,000	43,450	72,900
SX61	24,975	8,325	10,650	99,100	143,050
PUR12	12,300	0	0	0	12,300
S25	22,800	7,000	0	0	29,800
SA2	3,000	0	0	0	3,000
S301	5,000	0	40,000	0	45,000
PUR34	12,400	0	0	0	12,400
S365	1,000	0	25,000	0	26,000
Austree C	775	0	0	0	775
Austree L	775	0	0	0	775
Austree F	1,275	0	0	0	1,275
S625	3,000	0	0	0	3,000
94009	1,500	0	0	0	1,500
94011	1,700	0	0	0	1,700
94012	1,625	0	0	0	1,625
94013	50	0	0	0	50
94014	162	0	0	0	162
94001	1,500	0	0	0	1,500
94003	150	0	0	0	150
94004	75	0	0	0	75
94005	1,375	0	0	0	1,375
94006	1,650	0	0	0	1,650
S19	50	0	0	0	50
GA88	850	0	0	0	850
SH3	3,000	0	0	0	3,000
Totals	203,962	76,939	105,300	351,137	737,338

APPENDIX

The following posters were presented at conferences in 2001. Larger copies (11x17) are available upon request. Contact Brian Kiernan, 315.470.4742; bdkierna@syr.edu.

Kiernan, B.D., T.A. Volk, J.A. Dickerson, A. Barber, D. Barber and S. Butts. 2001. Developing a living willow snowfence program for New York State. Northeast Agroforestry and Carbon Conference, Binghamton, NY October 2-4.

Tharakan, P.J., T.A. Volk, C.L. Lindsey, S. Edick, J. Dickerson, P. Ray and L.P. Abrahamson. 2001. Growing willow biomass crops on conservation reserve program (CRP) land in New York State: An economic assessment. Northeast Agroforestry and Carbon Conference, Binghamton, NY October 2-4.

White, E.H., L.P. Abrahamson, T.A. Volk. 2001. Willow bioenergy crops for greenhouse gas reductions by co-firing. Environmental Monitoring, Evaluation and Protection in New York: Linking Science and Policy Conference, Albany, NY September 24-25.