# DEVELOPING A WILLOW BIOMASS CROP ENTERPRISE FOR BIOENERGY AND BIOPRODUCTS IN THE UNITED STATES

T.A. Volk[1], L.P. Abrahamson[1], E.H. White[1], E. Neuhauser[2], E. Gray[3], C. Demeter[3], C. Lindsey[3], J. Jarnefeld [4], D.J. Aneshansley[5], R. Pellerin[5] and S. Edick[6]

[1] State University of New York College of Environmental Science and Forestry
133 Illick Hall, Syracuse, NY, USA, 13210
[2] Niagara Mohawk Power Corporation, 300 Erie Blvd., Syracuse, NY, USA,13202
[3]Antares Group, 4351 Garden City Dr., Landover MD, USA, 20785
[4] New York State Research and Development Authority, 286 Washington Ave. Extension, Albany, NY, USA, 12203-6339
[5] Dept. of Agricultural and Biological Engineering,
Cornell University, Ithaca, NY, USA, 14853
[6]South Central NY RC&D, 99 North Broad St., Norwich, NY, USA 13815

## ABSTRACT

Years of research on short-rotation woody crops in New York, combined with growing concern about environmental issues, prompted the formation of the Salix Consortium in 1994. Over 20 organizations have collaborated to facilitate the development of willow biomass crops. This crop will provide a renewable feedstock for bioenergy and bioproducts that produces multiple rural development and environmental benefits.

Midway through the Biomass Power for Rural Development project over 242 ha (600 acres) of willow biomass crops have been planted in New York State. Regional trials have been established in nine states and Canada. The near term use for willow biomass crops is co-firing with coal. The Greenidge power plant has demonstrated continuous co-firing for several years. A successful test firing of willow biomass has been performed. Co-firing retrofits at the Dunkirk power plant have been completed, with tests scheduled for the fall of 2000. Research is underway on the fabrication of materials and chemicals from willow biomass that are currently derived from non-renewable fossil fuels. Continuing research gains in crop yields, reductions in production costs, and the quantification and valuation of environmental and rural development benefits, will be essential to the establishment of a commercial willow biomass enterprise.

**Keywords:** Salix, short rotation woody crops, co-firing, rural development

## BACKGROUND

The development of a willow biomass production system for the Northeastern and North-Central 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 1994 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 Biomass Power for Rural Development program supported by the United States Department of Energy and Department of Agriculture. Additional support has been received from a variety of sources including NYSERDA, US Department of Agriculture, Electric Power Research Institute (EPRI), Oak Ridge National Laboratory (ORNL) and others. During this program, the Consortium will investigate and assess critical aspects and questions concerning the commercial development of willow biomass for bioenergy and bioproducts 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 renewable feedstock for bioenergy and bioproducts for the Northeastern and North-Central regions of the United States. The production of the crop will simultaneously produce multiple environmental and rural development benefits. The Salix Consortium currently pools the research and investment interests of over 20 corporations, associations, universities, conservation groups, environmental organizations, and regional and national government agencies to develop this crop to a pre-commercial demonstration and commercial production stage.

The challenge facing the Salix Consortium is to simultaneously optimize production, develop farmer interest, increase crop acreage, and add a new fuel to the power supply and a new feedstock to the value added bioproducts markets. The bioproducts being developed will replace fossil fuel based products. These various end uses will provide an array of markets for producers. The scenario is challenging because there is currently not enough willow biomass established to fulfill a power producer's needs, while at the same time there are currently no long- term commitments that will assure producers that there will be a stable market for their crop in the future. In addition, restructuring of the energy industry in New York and other states has changed the degree of participation among some Consortium members. While there are promising markets for bioproducts on the horizon, none of them are commercialized.

In order for the Salix Consortium's commercialization efforts to be successful, the participation of farmers and landowners, businesses, and local and regional governments is essential. The Consortium has designed and implemented a multi-pronged approach to elicit this participation. These avenues include a focused outreach and education effort (Volk et al. 1999), the active involvement of potential producers of willow biomass crops (Edick and Brown 2000), and the development of an economic and business opportunity model for willow biomass crops (Lindsey et al. 2000).

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 $ha^{-1}$ (6,180 plants $acre^{-1}$), and mechanical harvests on three to four year cycles (Volk et al. 1999). Willows were selected for the Northeastern and North-Central 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 fertilized and irrigated willow grown for three years have exceeded 27 odt $ha^{-1}$ $yr^{-1}$ (12 odt $acre^{-1}$ $yr^{-1}$) (Adegbidi et al. in review). First rotation, unirrigated trials in central New York have produced yields of 8.4 to 11.6 odt $ha^{-1}$ $yr^{-1}$ (3.7 to 5.2 odt $acre^{-1}$ $yr^{-1}$) (Adegbidi 1999). Unirrigated, second rotation yields of the five best producing willow clones have increased by 18 - 62% compared to the first rotation (Volk, unpublished data). It is anticipated that commercial yields will be slightly lower due to variability in field conditions. Several efforts are underway to improve the yields of willow biomass crops. Traditional breeding efforts have been conducted at SUNY - ESF since 1998. Over the last three years over 250 controlled crosses have been made. The first set of F1 progeny have gone through an initial screening and have been planted in field trials in New York, Pennsylvania, and Maryland in the spring of 2000. Yields of commercial varieties from breeding efforts in Sweden have increased by 10 – 36% (Larsson et al. 1998). Similar gains are expected from efforts at SUNY – ESF. With support from ORNL, the Willow Crop Development Center for the Northeast and North-Central United States was established at SUNY – ESF in 2000. The Center will focus on expanded collections of native willows in the Northeast and North-Central United States as well as additional breeding and evaluation. Additional improvements in yields will be realized by optimizing the production system in terms of integrated pest management (especially weed control), selection of the best clones for different sites, and fertilization.

The near-term energy market strategy that the Salix Consortium is focusing on for willow biomass is co-firing at pulverized coal power plants. The 104 MW Greenidge pulverized coal power plant in central New York has been retrofit and has demonstrated continuous co-firing of wood at 10% by heat input for over three years. A successful test firing of willow biomass at Greenidge has been performed. This experience provided insight into some key issues, particularly the size distribution of willow chips that need to be addressed in order to assure efficient use of the willow energy crop. This concern is being addressed by the acquisition of a Bender harvester, which has a proven record in Europe. The Bender cuts and immediately chips the crop producing a consistent and acceptable size of chip (Pellerin et al. 1999).

As a part of utility restructuring in the state, NYSEG sold the Greenidge power plant to AES. While this plant remains a potential market for willow biomass, the future participation of the new owners is still being determined. NMPC successfully completed a set of initial wood co-firing tests at the 400 MW Dunkirk power station in western New York State. The co-firing retrofit on one 96 MW boiler at the station has been completed under the station's new owner, NRG Energy Inc. Test burns with willow and other wood biomass are planned for the fall 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 the winter of 2001/2002 when the first 40 ha (100 acres) of willow biomass crops are harvested.

Increased effort is being focused on the fabrication of new biobased materials and chemicals from willow biomass as an alternative to products currently derived from non-renewable fossil fuels. These products including biodegradable plastics; pharmaceutical agents; cellulose nanocrystal preparation, modification and applications; stimuli responsive elastomers; and the development of micron-sized dispensers for insect pheromones. Preliminary tests at the Empire State Paper Research Institute at SUNY - ESF have shown that willow biomass can be successfully pulped to obtain fibers with good paper making potential (Cheshire et al. 1999). The development of these value-added bioproducts will provide several new markets for producers.

A major benefit of the willow biomass cropping system is the production of environmental and social benefits simultaneously with renewable energy and bioproducts. 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. Initial assessments of the rural development benefits associated with a willow biomass enterprise indicates that about 76 direct and induced jobs will be created for every 4,040 ha (10,000 acres) of willow established (Proakis et al. 1999). SUNY - ESF is actively researching some potential environmental benefits including:

1. quantification of changes in soil carbon under willow biomass crops over time (Ulzen-Appiah et al. 2000),
2. phytoremediation of contaminated sites with willow biomass crops,
3. the use of willows as nutrient filters in riparian zones and as part of on-farm manure management systems,
4. the use of willow and poplar as an alternative cover for landfills,
5. the application of biosolids or manures on willow biomass crops,
6. the development of living willow snow fences.

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 feedstock for bioenergy and bioproducts in a restructured industry. 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 $MMBtu^{-1}$ 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 – 0.60 /$MMBtu^{-1}$ 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 willow biomass are worthwhile 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 commercialization 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.

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

| **Study Title** [a] | **Production System Benefit** | **Issue Addressed** |
|---|---|---|
| **Production System Research** | | |
| Genetic Improvement of Willows | 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 different willow clones and designing control strategies to minimize impacts. |
| Effect of Slow-Release Nitrogen Fertilization on Aboveground Biomass Production. | Slow-release nitrogen will improve yields and be less environmentally detrimental than other types of N fertilizer. | Recommended rates of nitrogen fertilizer application to optimize biomass production rates of willow. |

| Table 1. Research underway by SUNY - ESF and other Salix Consortium partners (cont'd). | | |
|---|---|---|
| **Study Title** [a] | **Production System Benefit** | **Issue Addressed** |
| Biosolids as Organic Soil Amendments in Willow Bioenergy Plantations | Lower production costs by replacing commercial nitrogen fertilizers and provide a productive use for biosolids. | Mineralization rates of nitrogen from biosolids, heavy metal and nutrient movement, and willow growth response. |
| Alternative Methods of Site Preparation | Minimize 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. |
| Clone-Site Testing and Selections for Scale-up Plantings | Parameters for clone site relationships will enhance yields and reduce costs | Survivability and yields of various clones over wide range of climate and soil conditions |
| Clonal Selection Trial and 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 characterized. |
| Aboveground Biomass Equation Development for Willow and Poplar Clones | 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) | Optimize 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 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 | Optimized weed control will ensure crop survival, higher yields, and lower | Effectiveness of different mechanical and chemical weed control practices. |
| **Environmental Studies** | | |
| Impact of Willow on Diversity of Soil Microarthropods | Quantification of the sustainability of willow biomass systems. | Belowground biodiversity impact of sustained willow production. |

| Table 1. Research underway by SUNY - ESF and other Salix Consortium partners (cont'd). | | |
|---|---|---|
| **Study Title** [a] | **Production System Benefit** | **Issue Addressed** |
| Avian Biodiversity in Willow and Poplar Biomass Crops. (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 soil sustainability and quantifying 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 in optimizing management practices. | Improve understanding of fine root longevity, distribution, biomass, and turnover. |
| [a] Studies are being directed by SUNY-ESF unless noted otherwise. | | |

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 Nursery (STN) and the SUNY - ESF's research station in Tully, NY. 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 (10 inch) 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. Planting stock production was down slightly to 1.41 million cuttings in 1999/2000 due to the severe drought and restrictions imposed on irrigation systems at both locations. Whip production was considerably lower in 1999/2000 due to limited growth of a number of clones during the drought. 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 $ha^{-1}$ (12,120 to 14,140 plants $acre^{-1}$) and concentration of effort at central locations, compared to the commercial planting density of about 15,300 plants $ha^{-1}$ (6,180 plants $acre^{-1}$) at scattered locations, increases the efficiency of the operation. Initial assessments indicate that the cost per cutting is reduced by 10 - 17% when whips rather then cuttings are produced. Production costs for material from cutback operations on is up to 100% greater than material from cutting orchards due to increased labor and transportation costs.

## Demonstration Areas in Western New York

Since 1998 the Salix Consortium planted over 242 ha (600 acres) of willow biomass crops in western New York within a 60 km radius of the Dunkirk power plant. All of the sites were in a hay crop the previous year or had been fallow for one to five years. These types of field conditions are common across New York because the agriculture industry, and in particular the dairy industry, has been in decline over the past decade. The 242 ha (600 acres) are spread over 14 landowners, with field sizes ranging from 2 ha to 40 ha (5 to 100 acres). Smaller fields were immediately adjacent to one another so that no collection of fields was smaller than 8 ha (20 acres) in size. Four to six different willow clones were planted in each set of fields. Two clones of hybrid poplar are being planted and assessed for use in the high density, double row system. Planting was done with both modified Fröebbesta planters that use 25 cm (10 inch) long cuttings and the Step planter that uses 1.25 – 2.5 m long whips. Field assessments indicate that the modified Fröebbesta machines planted at a rate of 0.25 ha $hr^{-1}$ (0.6 acres $hr^{-1}$) while the Step planter operated at a rate of 1.0 $hr^{-1}$ (2.5 acres $hr^{-1}$), including time for reloading and turning around at the end of the fields (Phelps et al. 1999). These types of gains in efficiency in the production system will improve the commercial viability of the system.

Table 2. Cutting and whip production in 1998/99 and 1999/2000 at SUNY-ESF and the New York State Department of Environmental Conservation Saratoga Tree Nursery.

| | SUNY-ESF | | Saratoga Tree Nursery | | Total | |
|---|---|---|---|---|---|---|
| | 1998/99 | 1999/2000 | 1998/99 | 1999/2000 | 1998/99 | 1999/2000 |
| Cuttings [1] | 225,000 | 274,000 | 446,000 | 563,000 | 671,000 | 837,000 |
| Whips [2] | 300,000 | 149,000 | 528,000 | 426,000 | 828,000 | 575,000 |
| TOTAL | 525,000 | 423,000 | 974,000 | 989,000 | 1,499,000 | 1,412,000 |

[1] Data presented is for 25 cm (10 inch) long cuttings
[2] Data presented is for 19 cm (7.5 inch) long cuttings

## Regional Expansion

Interest in willow biomass crops continues to grow across the Northeast and North-Central regions of the United States. Over the past seven years clone-site and genetic selection trials have been established in nine states, and the province of Quebec in Canada. 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 (1.2 to 2.5 acres) in size. At each site between six and 40 different clones of willow and poplar are being screened for their suitability to different soils and climate conditions.

## Future Plans

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 called for a three-fold 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, efforts will continue to develop and commercialize a range of bioproducts that use willow biomass crops as a feedstock. The Consortium will continue to quantify and promote the valuation of environmental and rural development benefits associated with the system. 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.

## REFERENCES


Abrahamson, L.P., E.H. White, C.A. Nowak, R.D. Briggs, and D.J. Robison. 1990. Evaluating hybrid poplar clonal growth potential in a three-year-old genetic selection field trial. Biomass 21:101-114.

Adegbidi, H.G., T.A. Volk, E.H. White, R.D. Briggs, L.P. Abrahamson and D.H. Bickelhaupt. (In review for Biomass and Bioenergy). Biomass and nutrient removal by willow clones in experimental bioenergy plantations in New York.

Adegbidi, H.G. 1999. Organic residuals as soil amendments for willow biomass crops: Impact on biomass production and soil nitrogen dynamics. Ph.D. Thesis, SUNY - ESF, Syracuse, NY. 222pp.

Armstrong, A., C. Johns, and I. Tubby. 1999. Effects of spacing and cutting cycle on the yield of poplar grown as an energy crop. Biomass and Bioenergy 17:305 – 314.

Cheshire, E., S.G. Granzow, and H. Makkonen. 1999. Kraft pulp from plantation grown biomass willow. ESPRA Research Report 111:25-29.

Edick, S. and A. Brown. 2000. Biomass Producers: Key partners in development of bioenergy enterprises. In Proceedings of Bioenergy 2000, Buffalo, NY, October 15 – 19.

Kenney, W.A., R.L. Gambles, and B.J. Vanstone. 1996. Willow biomass prototype farms of the University of Toronto: Status and future plans. In Karau, J. (Compiler). Proceedings of the Canadian Energy Plantation Workshop, Gananoque, Ontario, May 2-4, 1995. pp 19 – 22. Natural Resources Canada, Canadian Forest Service, Ottawa.

Kopp, R.F., E.H. White, L.P. Abrahamson, C.A. Nowak, L. Zsuffa, and K.F. Burns. 1993. Willow biomass trials in central New York State. Biomass and Bioenergy 5(2): 179 – 187.

Larsson, S., G. Melin, and H. Rosenqvist. 1998. Commercial harvest of willow wood chips in Sweden. In Kopetz, H., T. Weber, W. Palz, P. Chartier, and G.L. Ferrero (Eds.). Proceedings of the 10th European Conference and Technology Exhibition, Biomass for Energy and Industry, Würzburg, Germany, June 8 – 11, 1998. pp 200 – 203.

Neuhauser, E.F., T.M. O'Meara, W.H. Benjamin, L.P. Abrahamson, D.J. Robison, T. Rooney, and E.H. White. 1995. Economic Development through Biomass Systems Integration. EPRI Project Rep. No. 3407-20, Palo Alto, CA. 115pp.

Pellerin, R.A., D.J. Aneshansley, A.E. Phelps, L.P. Abrahamson, and T.A. Volk. 1999. Evaluation of Tree Harvesters and Delivery Systems for Short Rotation Willow Crop. Presented at the 1999 ASAE/CSAE-SCGR Annual International Meeting, Paper No. 995055.

Phelps, A.E., D.J. Aneshansley, R.A. Pellerin, L.P. Abrahamson, and T.A. Volk. 1999. Planting and Harvesting Salix (Willow): Measurement of Economic Factors as a Function of Field Location. Presented at the 1999 ASAE/CSAE-SCGR Annual International Meeting, Paper No. 995036.

Proakis, G.J., J.J. Vasselli, E.H. Neuhauser, and T.A. Volk. 1999. Accelerating the commercialization of biomass energy generation within New York State. In Overend, R.P. and E. Chornet (Eds.). Proceedings of the Fourth Biomass Conference of the Americas. Biomass: A Growth Opportunity in Green Energy and Value-Added Products, Oakland, CA. August 29 – Sept. 2, pp. 1711 – 1716.

Ulzen-Appiah, F., R.D. Briggs, L.P. Abrahamson, and D.H. Bickelhaupt. 2000. Soil carbon pools in short rotation willow (*Salix dasyclados*) plantation four years after establishment. In Proceedings of Bioenergy 2000, Buffalo, NY October 15 – 19.

Volk, T.A., L.P. Abrahamson, E.H. White, R.F. Kopp, and C.A. Nowak. 1999. Producing Short-Rotation Willow Crops in the Northeastern United States. In Hartsough, B.R. (Compiler). Proceedings of the Second Short-Rotation Wood Crops Operations Working Group Conference. Portland, OR August 24-28, 1998. pp 7 – 15.

Volk, T.A., S. Edick, S. Brown, and M. Downing. 1999. Community outreach and education: key components of the Salix Consortium's willow biomass project. In Overend, R.P. and E. Chornet (Eds.).Proceedings of the Fourth Biomass Conference of the Americas. Biomass: A Growth Opportunity in Green Energy and Value-Added Products, Oakland, CA. August 26-29, pp 1733 – 1738.

White, E.H., L.P. Abrahamson, and D.J. Robison. 1995. Commercialization of willow bioenergy – A dedicated feedstock supply system. In Proceedings of the Second Biomass Conference of the Americas: Energy, Environment, Agriculture, and Industry. August 21 – 24, 1995, Portland, Oregon. pp1534 – 1546.