EVALUATION OF SWITCHGRASS AND SHORT-ROTATION FORESTRY WILLOW IN EASTERN CANADA AS BIO-ENERGY AND AGRI-FIBRE FEEDSTOCKS

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ABSTRACT

In 1992 REAP-Canada began to evaluate the potential of switchgrass and short rotation forestry (SRF) willow plantations for biomass production on three sites in eastern Canada. The research work was cost-shared by three Canadian government departments for the purpose of assessing production costs and productivity of these crops as bioenergy feedstocks. Now in their fifth year of growth, these sites are being jointly used for both bioenergy and agri-fibre research purposes in cooperation with industry and university research partners. The most promising development of the research has been the emergence of switchgrass as a low cost feedstock for the pulp and paper industry. The fibre properties and pulp yields of switchgrass are similar to those of hardwoods, and no significant quality or processing barriers have been identified to limit its commercialization. Switchgrass yields at the sites managed by REAP-Canada continue to demonstrate the species' ability to provide stable and productive yields under a wide range of climatic conditions. SRF yields were lower than switchgrass during the establishment phase but have increased over the past two years. In 1996, the research and development program was expanded with further support from Natural Resources Canada and several industry partners to include assessments of the productivity of commercial plantations and to optimize the supply system for the pulp and paper industry.

KEYWORDS

Agri-fibre; bioenergy; biomass; short rotation forestry; switchgrass; willow

INTRODUCTION

REAP-Canada began investigating biomass crops with the objective of developing new perennial crops that could help society solve two of its most pressing environmental problems, global warming and deforestation. With support from Agriculture Canada, Energy Mines and Resources Canada and Forestry Canada, two promising perennial biomass energy crops were assessed. Prior to this time there had been no assessment of switchgrass as a biomass species in Canada and no scale up of SRF willow. The two systems were directly compared in terms of economics and production performance under the same management at three sites of varying soil type. This paper will summarize the major agronomic findings and promising commercial applications for the material. The economic performance of the crops has been reported previously (Girouard *et al.*, 1994; Girouard *et al.*, 1996).

EXPERIMENTAL DESIGN

The main focus at the beginning of the research project was the establishment of three quasi-commercial plantation sites of approximately 5 ha each. At the Lods Agronomy Research Centre in Ste Anne de Bellevue, Quebec, two sites were established: the Ecomuseum and Seed Farm sites. A third site was established at the Ignatius farm near Guelph, Ontario. The SRF willow and switchgrass plots were planted as main plots with six replications at each site. Subplots consisted of varieties, with at least three different willow clones and three switchgrass cultivars established at each site. To enable between-site yield comparisons, Cave-in-Rock switchgrass and the *Salix alba x glatfelteri* 1 (SAG-1) willow clone were established at all three sites. The Ignatius farm site was eliminated from the study at the end of the 1994 season because of budget constraints.

AGRONOMIC PERFORMANCE

Weed control was the greatest challenge to establishing switchgrass and SRF willow plantations. In the case of switchgrass, the Ecomuseum site had heavy annual grass pressure which delayed establishment of the crop in 1993 and reduced productivity during the first production year of 1994. In SRF willow, excellent weed control could be achieved through the combination of herbicides and mechanical cultivation well into late spring. However, the crop was not competitive and late weed flushes caused major problems at several sites. Periodic outbreaks of European willow sawfly (*Nematus* sp.) were also experienced during from the late summer of 1994 through to the spring of 1996. The outbreaks appeared to be concentrated on young, rapidly growing trees in their first or second year of growth or in the first year following coppicing. Other insect and disease problems also damaged specific willow clones but damage was generally minimal with the SAG-1 willow clone. Switchgrass appeared to be less suitable for cultivation on the poorly drained clay loam soil found in the lower sections of the Ecomuseum site and SRF willow less suitable for cultivation on the shallow fine sandy loam sections of the Seed Farm site and the well drained sections of loam soil at the Ignatius site.

Table 1. Cave-in-Rock switchgrass and SAG-1 willow yields from the plantation sites (1994-96).

	1994	1995	1996	Average
Seedfarm Site		odMg/ha/yr		
Switchgrass	9.7	11.0	11.9	10.9
SRF Willow	4.4	11.6	6.6	7.5
Ecomusem Site				
Switchgrass	7.9	9.6	12.7	10.1
SRF Willow	9.4	8.8	7.6	8.6
Ignatius Site				
Switchgrass	8.1	na	na	na
SRF Willow	1.9	na	na	na

In a different series of plots, a trial evaluating ten switchgrass and warm season grasses at the Lods Agronomy Research Centre demonstrated that the Cave-in-Rock switchgrass used in the plantations was one of the best adapted varieties for the region, yielding an average of 12.6 odMg/ha over the years since its establishment in 1992 (Figure 1). Cave-in-Rock, along with other more southerly originating materials such as Carthage, Pathfinder and Blackwell, had a longer period to the hard dough stage of seed maturity than the other varieties which enabled a better use of the solar radiation available during the growing season.

Overall, once the crops were fully established, fall-harvested switchgrass yields from the plantation sites were in the 10-13 odMg/ha range and SRF willow yields in the 7-11 odMg/ha range (Table 1). These yield levels would result in a minimum market price of $38-$51/odMg and $63-95 odMg/ha for switchgrass fibre and SRF willow, respectively (Girouard *et al.*, 1996).

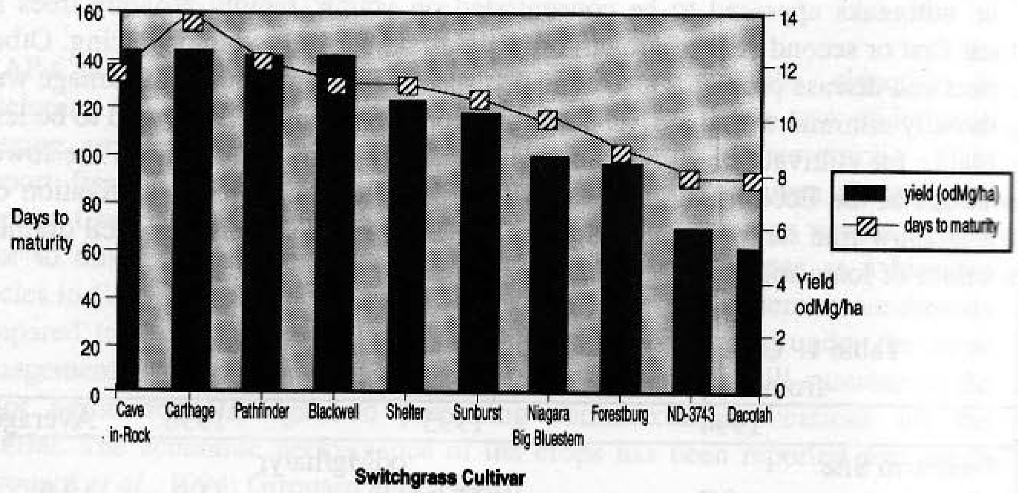

Figure 1: Yield (odMg) of switchgrass cultivars at Ste Anne de Bellevue, Quebec (1993-1996)

REAP-Canada, in partnership with McGill University, is currently assessing the carbon sequestration potential of SRF willow and switchgrass plantations as part of a low cost carbon offset strategy (Zan *et al.*, 1997). Both perennial crops appear to have excellent energy balances, with SRF willow and switchgrass respectively producing 32.5 and 35.0 times as much energy as they require for their production (Samson *et al.*, 1997). Switchgrass has potential as a renewable energy crop feedstock and its development would be facilitated if carbon taxes were imposed on fossil fuels or a carbon credit could be given to bioenergy plantations. However, at a minimum market price of $63-95/odMg, it appears doubtful SRF willow could become an economically viable bioenergy feedstock.

AGRI-FIBRE OPPORTUNITIES

Realizing that energy markets alone may not provide enough economic incentive to grow SRF willow or switchgrass crops, research partners interested in evaluating these crops as pulp and paper feedstocks were identified. In 1994, the Pulp and Paper Research Institute of Canada (PAPRICAN) in Pointe Claire, Quebec evaluated SRF willow coppice as a potential feedstock. They were able to successfully fractionate white fibre in the wood chips from bark, foliage and decayed wood through the PAPRIFER process. The biggest barrier to the concept appeared to be that the white fibre yield was too low after the oversized chips and bark were removed. As a result only approximately 2/3rds of the original material was suitable for pulping. With a willow delivery cost of $63-95/odMg prior to processing losses, coppiced willow appeared to be too expensive a raw material to be used for pulping.

In 1995, REAP also supplied switchgrass to several paper companies and to the Centre Specialise en Pate et Papier (CSPP), a research organization in Trois Rivieres, Quebec. No previous research projects could be identified which evaluated the potential of switchgrass for pulping. However, a major agri-fibre research project conducted in the United States in the late 1950's, did identify big bluestem (Andropogon gerardii), another dominant tall grass prairie species, as a promising candidate species for papermaking (Nieschlag *et al.*, 1960). The recent assessments of switchgrass have identified the material as a hardwood substitute. Fibre characteristics, pulpability and bleachability of the material have now been described (CSPP, 1995; Radiotis *et al.*, 1996).

Promising results with perennial grasses as agri-fibre feedstocks have also been reported in Scandinavia as a result of an extensive screening program of agricultural residues and fibre crops begun in 1990. Reed canary grass pulping has now been identified by Scandinavian researchers as a breakthrough in agri-fibre utilization as a hardwood substitute in the production of fine-quality papers (Paavilainen and Tulpalla, 1996). The researchers found that overwintering reed canary grass caused the material to lose many of its leaves which resulted in higher pulp yields and better drying conditions for harvest and lower nutrient extraction. The major disadvantage of the system was that the yield was reduced by approximately 20-30% through the overwintering process.

REAP to evaluated overwintering losses in switchgrass in partnership with a major pulp and paper firm and found similar losses (Radiotis *et al.*, 1996). The agronomic advantages of spring harvesting include maximized nutrient recycling, optimal winter survival and reliable drying conditions for harvest. The main losses are of leaves and seed heads which have lower fibre quality. As a result, overwintering perennial grasses creates higher pulp yields and a better quality pulp as it has longer fibres, less fines, and greater brightness (Hemming *et al.*, 1994; Radiotis *et al.*, 1996).

A comparison of the two species reveals that switchgrass is superior to reed canary grass as an agri-fibre feedstock in regions where both crops can be grown. From an agronomic standpoint, switchgrass has higher yield potential, less lodging, lower N, P and K requirements, greater productivity, better suitability to a one-cut harvest regime, a much longer window of opportunity for spring harvesting, and better adaptation to the dryer soil types which are most desirable for early spring harvesting (Samson and Omielan, 1994). The agronomic advantages of reed canary grass over switchgrass include adaptation to cooler northern regions and wet soils. Few direct comparisons of switchgrass and reed canarygrass have been performed for specific pulping traits; however, switchgrass appears to have a lower ash content and a higher cellulose content (Cherney *et al.* 1990; Radiotis *et al.*, 1996).

RESEARCH DIRECTIONS

REAP is undertaking further work to in order to examine the characteristics of current switchgrass ecotypes for stem, leaf sheath, leaf and panicle percentages. An additional project currently underway is the scale-up of two farm sites in eastern Ontario and southwestern Quebec for the purpose of assessing strategies to minimize harvest and overwintering losses, and optimize storage and transport systems for the pulp and paper industry. The project will also confirm yield data for the production of switchgrass under commercial farming conditions and assess the energy co-product potential of switchgrass when its principal use is as a pulp feedstock.

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