THE POTENTIAL ROLE OF PERENNIAL GRASSES IN THE PULP AND PAPER INDUSTRY

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ABSTRACT: Perennial grasses have been identified in Canada and Scandinavia as close substitutes for hardwood trees in pulp and paper applications. For existing mills located in agricultural regions, these dedicated fibre crops could provide a stable, cost-competitive supply of fibre with a quality superior to most agricultural residues.

KEYWORDS: perennial grasses, switchgrass, reed canarygrass, hardwood, agricultural fibre, straw, corn stover.

INTRODUCTION

Wood established itself as the dominant fibre source in the pulp and paper market in the last century. Technological innovations resulted in the economic preference of wood over agricultural fibres that were used previously in the industry. Agricultural sources of fibre for papermaking are being re-evaluated in Europe and North America as an option to improve the competitiveness of the pulp and paper industry, particularly as sources of wood fibre become increasingly scarce. Agricultural fibres in North America include residues from food crop production such as cereal straw, annual dedicated fibre crops (crops planted with the sole purpose of fibre production) such as hemp, kenaf and fibre flax, and more recently, perennial warm season grasses such as switchgrass. This article discusses the place that perennial grasses could have in the future portfolio of fibre sources available to papermakers in North America. The long-standing economic and technical barriers for the use of agricultural fibres are first discussed, followed by a review of current research on perennial grasses and their potential role in the papermaking industry.

OVERCOMING BARRIERS TO THE USE OF AGRICULTURAL FIBRES IN THE PULP AND PAPER INDUSTRY

As we enter a new century, we must ask ourselves whether new developments in agri-fibre feedstock supply and pulping systems can lead to sufficient technological innovation to once again have a major impact on the pulp and paper industry. For this innovation to occur, several barriers must be addressed (Table 1).

Firstly, before commitments are made to proceed with large investments in mills and research, paper companies need assurance that the fibre supply will be available for the years ahead. Security of supply has been a major deterrent to the use of agri-fibres in the past. Dedicated fibre crops can provide stability to the industry because long-term production contracts can be signed between paper companies and farmers for a given price, time period, and acreage. A mill using high yielding dedicated fibre crops would benefit greatly by being able to forecast its supply and cost for the coming years and by keeping its fibre supply within a short trucking haul. Crop residues do not offer the same level of stability, as farmers are reluctant to sign long-term supply contracts for the sale of a by-product that would restrict their cropping flexibility.

TABLE 1: TRADITIONAL SUPPLY BARRIERS TO THE USE OF AGRI-FIBRES IN NORTH AMERICA	
Barrier	**Solution**
• Infrastructure set to handle wood	Integrate agri-fibre lines into existing mills.
• Security of supply	Emphasize drought tolerant perennial fibre crops instead of residues.
• Low cost fibre does not always translate into low fibre cost per tonne of pulp	Use higher cellulose content sources like perennial grasses.
• High ash and silica content	Use species with intrinsically lower contents, overwinter material, source material from sandy soils and avoid soil contamination by using perennials.
• Logistics of supply systems/material bulkiness	Grow high yielding crops that can be grown within a short distance of a mill, use high density square balers and new fabric covered outdoor buildings for on-farm storage; use leading-edge digester technology to reduce impact of material bulkiness on throughput.
• Short fibre length	Blend agri-fibres with wood fibres and improve fibre characteristics through investing in plant breeding (future research will determine maximum achievable gains)

Additionally, dedicated fibre crops have the potential to produce large volumes of material for pulping while the supply of crop residues is more limited. After accounting for agricultural needs such as animal bedding and soil conservation, only approximately 2 million tonnes per year of cereal straw are reliably available in the Prairies for industrial purposes [1]. In eastern Canada, the amount and spatial distribution of cereal straw available for industrial uses is not adequate to supply large pulp mills. Corn stalk utilization is possible as it is produced in eastern Canada, but climatic conditions prevailing at the time of harvest makes baling a dry, soil-free product relatively difficult.

Secondly, agricultural fibres have to be less expensive per tonne of pulp produced than wood fibre if they are to make reintroduction possible. Residues such as cereal straws are usually less expensive per tonne of fibre delivered to a mill, but are often in the same range on a per tonne of pulp basis. Strategies designed to reintroduce agri-fibres should focus on species with a significantly lower delivered cost than wood. At the same time, the species must provide similar pulping yields and quality attributes. In the case of dedicated fibre crops, plant-breeding improvements can facilitate the achievement of this goal. With the long-term downward trend in agricultural commodity prices, the outlook for procurement costs of dedicated agri-fibre appears attractive compared to wood fibre prices.

Thirdly, the high ash and silica content of most agricultural fibres have been factors limiting their use for papermaking. Switchgrass management for pulp and paper applications can produce fibre for pulping with an ash content of 3%, which compares favorably to straw from Western Canada with 6-10% ash [2]. These reductions, combined with the potential for sharing black liquor treatment infrastructure within an existing wood based mill, minimize the technical concerns about using moderate levels of agri-fibres in pulp and paper production. The capital-intensive nature of the pulp and paper industry, along with effluent treatment legislation in place in North America, strongly point to the scenario that agri-fibres will initially be used as add-on capacities to existing wood-based mills.

Finally, advances in the logistics of material handling of agri-fibres have been made. The uses of high-density (150 kg/m3) big square balers, and large stackers have reduced transport and handling costs [3]. Relatively low cost, on-farm fibre storage is now available from recently developed galvanized tube steel buildings with fabric covers.

Transportation costs can be also be minimized by using high-yield-per-hectare local sources of dedicated fibre crops.

Overall, developing high yielding, perennial grasses through a focused, coordinated effort offers the real possibility for a breakthrough in agri-fibre feedstocks utilization.

CURRENT RESEARCH ON PERENNIAL GRASSES

Perennial grasses are commonly used as forage crops, and in contrast to annual grasses, they do not need to be re-seeded every year. Grasses can be categorized into two broad groups, cool and warm season, based on their photosynthetic system.

Cool Season Perennial Grasses: Cool season grasses are C_3 plants (plants where the first stable products of photosynthesis are 3-carbon compounds). Other C_3 plants include wheat, hemp, and trees. In Scandinavia, reed canarygrass (*Phalaris arundinacea)* has been identified as having potential in that region after an initial screening program of 17 species [4]. Pulping trials in Finland and Sweden have found that it can produce a close substitute fibre for hardwood in the manufacture of fine quality paper [5]. Reed canarygrass is generally not very drought-tolerant, and requires a relatively good water supply and a moderately high fertilization rate to get good productivity. In the drier regions of western Canada, other more drought tolerant cool season perennial grasses are more productive [1], and merit investigation for their suitability for pulping.

Warm Season Perennial Grasses: Warm-season biomass crops have the C_4 photosynthetic cycle (photosynthesis initially yielding a

4-carbon compound) and include sugarcane (*Saccharum spp*.) and switchgrass (*Panicum virgatum*). Under optimal conditions, C_4 grasses are approximately 40% more efficient at converting solar radiation into biomass. C_4 grasses consume only approximately half as much water per tonne of biomass produced than do C_3 grasses. The high yield potential of switchgrass in temperate climates has created significant interest in it as a lignocellulosic biomass crop for fibre and energy markets [Table 2]. Switchgrass was a once dominant grass found in the North American tallgrass prairie.

Review of Current Research on Switchgrass: Switchgrass has been researched by REAP-Canada in Quebec and Ontario since the beginning of the 1990's, with support from Natural Resources Canada and Agriculture and Agri-Food Canada. The main objectives were to evaluate crop establishment, productivity, and production costs for switchgrass in comparison to fast growing hybrid willow trees. These studies, done on quasi-commercial sized sites, provided invaluable data for understanding cost and productivity differences for fast growing grasses and trees in Eastern Canada. On an equivalent yield basis, switchgrass was found to cost approximately 40% less to produce than fast growing willow trees. Research showed that in general, once the crop is fully established, yields were between 8-13 oven dry tonnes (ODT) $ha^{-1}yr^{-1}$ for an end of season fall harvest, and 6-10 ODT $ha^{-1}yr^{-1}$ for the early spring harvested crop (the difference being fibre losses occurring during the overwintering process [6,7]). Late season maturing varieties were found to be the most productive because they captured more of the available solar radiation during the growing season.

These productivity results helped prompt the creation of a partnership between REAP Canada, Domtar, Noranda and Natural Resources Canada to intensively evaluate switchgrass for papermaking. These studies found switchgrass to be easily pulped using the kraft, soda and soda-AQ processes with acceptable and similar pulp yields to wood (ie. A 49% total yields at a kappa number of 13)[7]. Switchgrass was also planted commercially on 6 ha fields on two farms in eastern Canada in the spring of 1996. The main objectives were to confirm yields and perform experiments required to optimize the fibre supply system. Switchgrass established well on the sites but weed pressure from annual grass weeds slowed establishment at one of the sites. Productivity has steadily increased at the sites and in 1999-averaged 12.5 ODT/ha. With support from the Ontario Agricultural Adaptation Council and the University of Guelph, REAP-Canada developed a production guideline for farmers and further expanded its research and development program in Eastern Ontario. In 1999, switchgrass was planted on 300 acres by Eastern Ontario farmers to supply a cellulosic ethanol plant. In the year 2000, commercial fields of the crop will be planted in Eastern Ontario and Quebec for livestock bedding. The crop also appears to be a promising substrate for producing compost for mushroom cultivation and as a pellet fuel for space heating. In eastern Canada, switchgrass appears to be headed towards commercialization for a variety of biomass uses.

PERENNIAL GRASSES FOR FIBRE UTILIZATION

The main advantage of perennial grasses is that they can produce more fibre per hectare of land than hardwood trees in most of North America and that they can be harvested each and every year. Coupled with production in close proximity to pulp and paper mills, this could result in a significant competitive advantage in the medium and long term for a number of North American facilities. In southwestern Quebec and southern Ontario, annual switchgrass yields, from 6 to 13 ODT $ha^{-1}yr^{-1}$, can be achieved with current cultivars, depending on the harvest regime. The more humid regions of the southern U.S. are the most productive in North America for switchgrass, with yields of up to 25 ODT $ha^{-1}yr^{-1}$ produced in research plots in Alabama [8]. Reed canarygrass usually produces between 7-11 ODT $ha^{-1}yr^{-1}$ in North America, however, similar to short rotation forest, productivity is frequently limited by soil moisture availability. Reed canarygrass would probably be the best candidate species for pulp mills in northern regions of Canada. In warmer regions, particularly Canada's corn growing areas, the climate is ideal for growing switchgrass successfully. Switchgrass, in comparison to reed canarygrass, has higher productivity, lower feedstock production costs and reduced ash content, which overall makes it more attractive in regions where both species can be grown.

For fibre production, the preferred harvest period at present for both reed canarygrass and switchgrass is the spring harvest: the crops are not cut in the fall but rather left in the field to overwinter and then harvested in early spring prior to regrowth. The main benefits of this strategy are to enable nutrients to leach back to the soil and to reduce the leaf content of the plant. Translocation of nutrients to the soil recycles nutrients for the next growing season, reducing the ash content of the feedstock that then minimizes black liquor treatment problems. Reduction in leaf content is important since plant analyses have indicated that the stem component has the best suitability for pulping, followed by the sheaths, and lastly the leaves [7]. The leaf fraction has value as a bio-energy source, and separation of the stem and leaf components for utilization in agri-fibre and energy markets, respectively, may expand opportunities for utilization of fall harvested crops for pulp and paper applications.

In regions such as Eastern Canada, where hardwood chips are delivered to pulp mills at $80-$100/ODT [10], switchgrass benefits from a cost advantage at the mill gate – an advantage that will grow as wood fibre supplies tighten. The most recent economic analysis of switchgrass production in Eastern Canada for use as a spring harvested crop for pulp places maximum delivered costs at $61-$81 tonne [9]. Estimates are mostly influenced by achievable yields and land opportunity costs.

With most switchgrass acreage on idle or inferior quality land, these grasses would provide additional farm receipts that would strengthen the rural economy. For instance, it has been estimated that adding 15% switchgrass pulp to the fine paper and hardwood market pulp currently produced in eastern Ontario and southwestern Quebec, would require less than 5% of the agricultural land base and provide new farm receipts of $20-40 million a year [10].

TABLE 2: ATTRIBUTES OF SWITCHGRASS FOR FIBRE PRODUCTION
• Stable and productive yields: 6-13 ODT $ha^{-1}yr^{-1}$
Drought tolerant and well adapted to marginal soils
Ash contents of 2.5-3.5 % for spring harvested material compared to 6-10% for cereal straws in western Canada
Minimizes competition for land with high value cash crops and provides access to agricultural land for fibre production that is not well suited for tree growing
Lower estimated delivered cost to mills than hardwood chips in eastern Canada.

CONCLUSION

The key to the production of a long term, stable, low cost supply of agricultural fibre for the pulp and paper industry is the development of high yielding crops adapted to lower quality farmland. Perennial grass fibre crops such as switchgrass meet both these criteria. The main role perennial grasses can play in the future portfolio of fibre sources in North America is to provide a large amount of hardwood substitute fibre within a relatively small radius of pulp mills located in agricultural regions. Traditional barriers to the use of agri-fibres such as low pulping yields, high ash content of feedstocks, and weak supply logistics have largely been overcome. In the coming years, concerns over the rising cost of wood fibre in Canada combined with minimal real growth in pulp prices will require innovation in the Canadian pulp and paper industry. The potential exists for a significant cost reduction in pulp and paper making through the use of furnishes including low cost fibre derived from perennial grasses. In the long-term further advances in plant breeding, material handling, as well as in pulp and papermaking technologies will be essential for agri-fibres to reach their full potential in the North American pulp and paper industry.

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