Development of Bioenergy Feedstocks:

Agronomy Data from Eastern Canada

Final Report

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EXECUTIVE SUMMARY

This project conducted assessments of switchgrass under various growing conditions and stand ages in eastern Canada. The aboveground productivity and biomass of switchgrass at the plantation sites was compared with short rotation (SR) willow, another perennial bioenergy crop, and corn, a conventional row crop at two sites in Ste-Anne-de-Bellevue, Quebec. The performance of miscanthus, a perennial grass, was also evaluated as part of program to identify and develop a range of perennial grass species best adapted to the growing conditions encountered in eastern Canada. Two on-farm switchgrass sites in Quebec were also evaluated.

The study indicated that in 1999, at Ste-Anne-de-Bellevue, SR willow aboveground productivity exceeded switchgrass and corn productivity at both sites. A stabilization in the SR willow (*Salix alba x glatfelteri*) annual incremental yields was noticed at approximately

20 Mg ha^{-1}, averaged for both sites. Switchgrasss yields of Cave in Rock switchgrass averaged 13 Mg ha^{-1} which is similar to yields in previous seasons. Overwintered switchgrass harvested in the spring of 1999 showed much higher losses (37-52%) than previous years. Corn grain yields averaged 8.6 Mg ha^{-1} over three years. This indicates that once established, bioenergy crops have the potential to have higher productivity than corn.

Switchgrass demonstrated high productivity at the two on-farm locations in Quebec; in St. Timothée, and in Pintendre, which a more northerly located site east of Quebec City. After four years the site in St. Timothée is approaching full stand establishment with yields peaking in 1999 at 12.7 Mg ha^{-1}. At the northern location of Pintendre, an excellent first year production year yield of 9.9 ODT/ha was obtained from Cave-in-Rock switchgrass. However other varieties had lower productivity which appeared to be related to the presence of a foliar disease.

Miscanthus was evaluated as another potential perennial bioenergy crop at the Lods Agronomy Seed farm in Ste. Anne de Bellevue, Quebec. Yields in the fourth season were found to be approximately 9 Mg ha^{-1} for both the 50 kg ha^{-1} and 100 kg ha^{-1} treatments. The crop appears adapted to the region but more productive clones likely need to be assessed in the future.

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INTRODUCTION

Switchgrass (*Panicum virgatum* L.) has been identified as a potential bioenergy crop for early commercialization. It is also a suitable crop for fiber (pulp and paper) production. Short rotation forestry willow (*Salix alba* sp.) is also a viable bioenergy crop. Both of these are perennial species, which do not require annual planting. With the growing concern of rising greenhouse gases (GHG) and rising oil prices, bioenergy crops are gaining importance in environmental as well as economic agendas. With the signing of the Kyoto Protocol, Canada committed to reduce its GHG emissions by 6% below 1990 levels, by the year 2008-2012. One immediate, long-term solution would be to implement bioenergy crops on marginal agricultural soils. These crops create a closed loop C cycle, by utilizing CO_2 for photosynthesis during their growing period, and releasing it during the combustion process. However, during the next growing cycle, the same amount of CO_2 that was released will be absorbed again through photosynthesis, provided equal amount of land is kept to bioenergy crops. In addition to the biomass C sequestration ability of the above ground material, biomass crops also have the potential to store C belowground, in their roots, and in the soil. The perennial nature of the bioenergy crops requires less field work to be carried out (less seeding and tilling) which also reduces the fossil fuel consumption from farm machinery use.

The main objective of this study was to develop a comprehensive set of data covering the agronomic potential of promising bioenergy feedstocks for eastern Canada. This project evaluates the agronomic traits and aboveground productivity of two bioenergy crops, switchgrass and SR willow, and compares them to a conventional row crop commonly grown in Quebec and Ontario; corn. Several of the sites are long term sites, utilized since 1993 for these comparisons. The total aboveground productivity represents yields obtained on farms, whereas the total aboveground biomass represents the total potential biomass obtained.

The study also evaluates switchgrass productivity in different climatic regions of Quebec; in St. Timothée, 40 km southeast of Montreal, and in Pintendre, near Quebec City. Another potential perennial grass bioenergy crop, miscanthus is also evaluated in this region under two fertilizer treatments at Ste Anne de Bellevue.

The data obtained from this study will help to determine which bioenergy crops, and in some cases, which varieties, hold the most potential in the immediate and long-term future for eastern Canada. The production of low cost raw material will be a fundamental requirement for the successful development of the bioenergy industry in Canada.

RESULTS

Task 1: Agronomy of Bioenergy Crops

1. Bioenergy Farming Systems Comparisons at Ste-Anne-de-Bellevue, Qc

   Two sites were evaluated for the agronomic traits of bioenergy crops. The sites contained side by side comparisons of fast growing tree species, perennial grasses species, as well as a conventional row crop. Each of the two sites consisted of approximately 5 ha, situated on the Macdonald Campus Emile. A. Lods agronomy research farm, of McGill University. The soils on the site were mainly St. Bernard and Chicot fine sandy loam, with pockets of Chateauguay clay loam. One site was referred to as the Ecomuseum, and the other as the Seedfarm site. Each site contained 6 blocks, with 3 treatments (short rotation willow (S*alix alba x glatfelteri* L.), switchgrass (P*anicum virgatum* L.) and corn (*Zea mays* L.)) arranged in a randomized complete block design (Figure 1.1 and Figure 1.2). Within the switchgrass plots, 3 different varieties of switchgrass were planted (Cave in Rock, Pathfinder and Sunburst), each of 6 m width. Within the short rotation (SR) willow, three varieties were planted (*Salix alba* sp., Miyabaena, and Viminalis). The main variety (*Salix alba* sp.) took up 14 rows, the others 8 rows. One variety of corn was planted each year.

   In 1993, the SRF willows cuttings were planted at a rate of 11 000 ha^{-1}, in 0.92 m wide rows. The trees were coppiced with thinning saws in January 1996, and fertilized with 77 kg N ha^{-1} and 84 kg K ha^{-1} in June 1996. In 1998 the willows at both sites were fertilized with 125 kg N ha^{-1}, 31 kg P $ha^{-1}$and 75 kg K ha^{-1}. In 1999 no fertilizer was applied.

   Switchgrass was planted in May 1993 with a Brillion grass seeder at a rate of 6 kg ha^{-1} at both sites. At the Seedfarm, the switchgrass was fertilized with urea at a rate of 45 kg N ha^{-1} in June 1994, 1995, 1996, and with 75 kg N ha^{-1} in June 1997. At the Ecomuseum, the switchgrass was fertilized with 30 kg N ha^{-1} applied as ammonium nitrate in June 1994. The rate was increased to 45 kg N ha^{-1} in June 1995, 1996, and 1997. In 1998 both sites received 50 kg N ha^{-1}, as urea. In 1999 both sites received 60 kg N ha^{-1}, as urea.

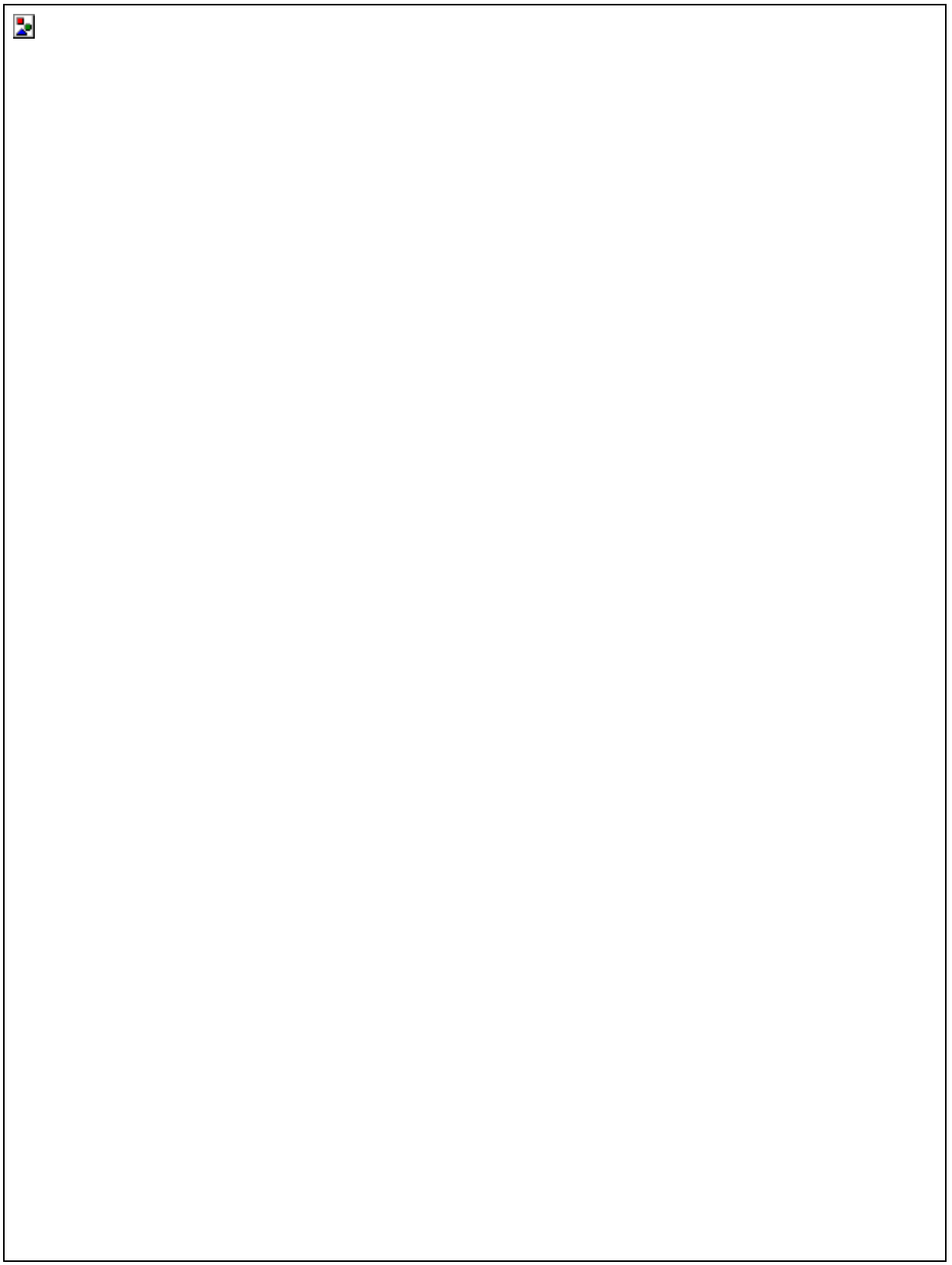
   Corn (hybrid Pioneer 3921) was sown in May 1996 at both sites, at a density of 80 000 plants ha^{-1}, in 0.76 m row spacing. The corn at the Seedfarm was fertilized with 205 kg N ha^{-1}, 104 kg P ha^{-1}, and 62 kg K ha^{-1}. The corn at the Ecomuseum was fertilized with 161 kg N ha^{-1}, 104 kg P ha^{-1}, and 62 kg K ha^{-}

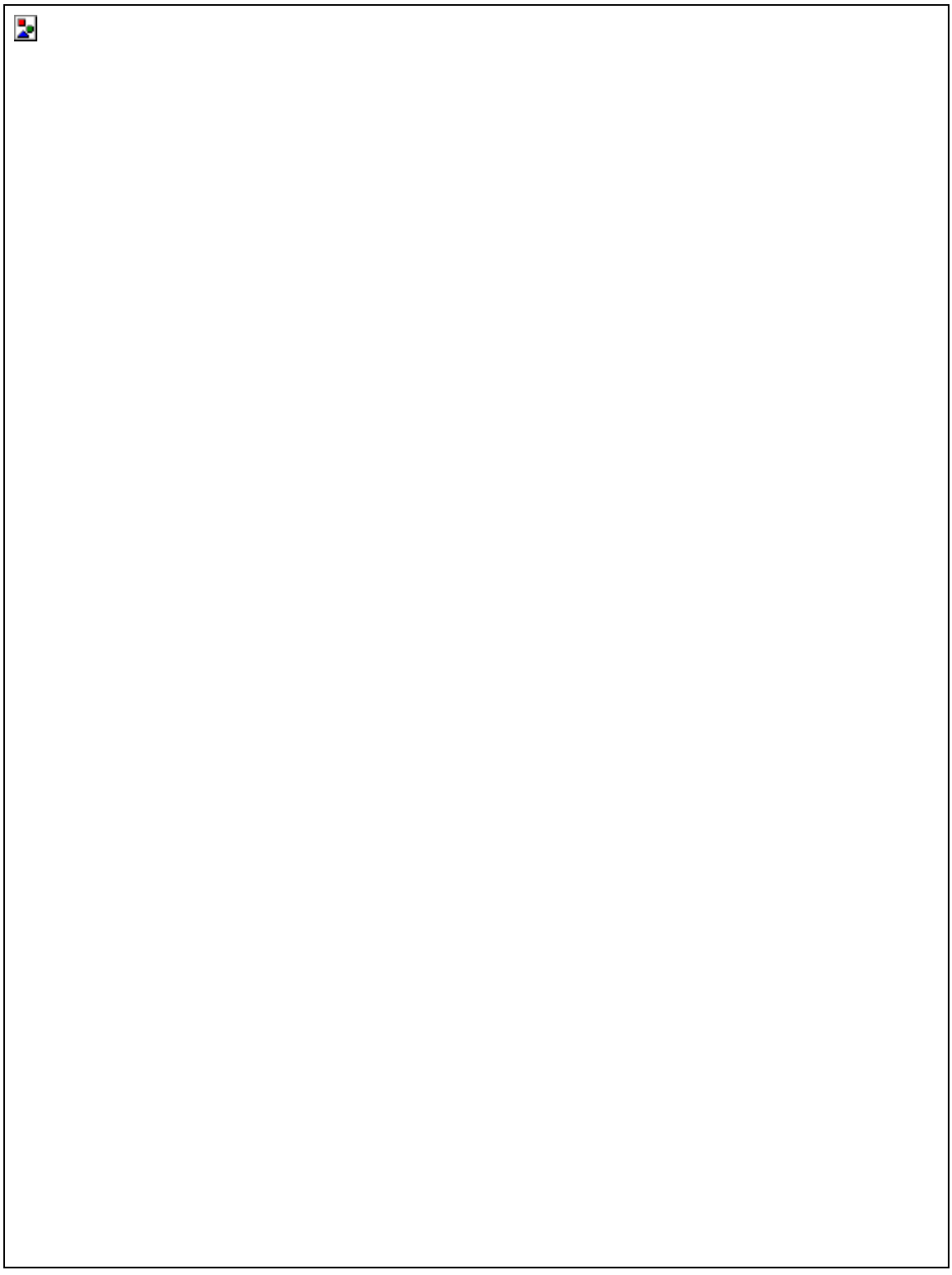
[1]. In 1997, corn (hybrid Pride K205) was sown in May. The Seedfarm received 162 kg N ha^{-1}, 104 kg P ha^{-1}, and 66 kg K ha^{-1} of fertilizer, and the Ecomuseum received 176 kg N ha^{-1}, 104 kg P ha^{-1}, and 66 kg K ha^{-1}. In 1998, the corn (Pioneer 3893) received 148 kg N ha^{-1}, 23 kg P ha^{-1} and 66 kg K ha^{-1}at both sites. In 1999 the corn (Pioneer 39K38) was fertilized with 147 kg N ha^{-1}, 23 kg P ha^{-1} and 66 kg K ha^{-1}, at both sites.

The annual mean precipitation, from May to October, at both sites, was 498.6 mm, the annual mean monthly temperature was 15.7^{o}C, and the corn heat units (CHU) totaled 3203.

Aboveground crop productivity assessments were carried out on all 3 crops in fall 1999. The aboveground productivity represented the yields obtained by using the required harvesting machinery. All three switchgrass varieties (Cave in Rock, Pathfinder and Sunburst) were harvested in both spring and fall, at 10 cm from the ground. The harvestable biomass (above 10 cm) of the *salix x alba glatfelteri* variety of SR willow, and the grain of the corn were only harvested in fall.

Total aboveground biomass was also harvested in each treatment and consisted of sampling the complete biomass from the ground up. This sampling was restricted to the Chicot fine sandy loam (Grey Brown Podzol) soil in order to compare the total amount of biomass that could potentially be reached for a given area, for purposes of biomass C sequestration. In addition to the corn, these harvests were only carried out on the Cave in Rock switchgrass variety, and the *salix x alba glatfelteri* variety of the SR willow.





Switchgrass

Switchgrass was harvested in spring (May 6 to 10) and in fall (October 15), in 1999, its sixth year after seeding. No pest or disease incidences were noticed during the growing season. From the spring results (Table 1.1.1), the moisture contents between the varieties did not differ, average moisture content was 13.2% at the Seedfarm, and 12.5% at the Ecomuseum. Differences in the moisture content of switchgrass varieties are rarely apparent after the overwinter period.

The yields were not different between the three varieties at the Seedfarm. At the Ecomuseum, the Sunburst had significantly lower yields (5.4 Mg ha^{-1}), compared with 7.1 and 7.2 Mg ha^{-1} for Cave in Rock, and Pathfinder, respectively. Sunburst is an early maturing variety and therefore senesces first in fall. Average yields for the switchgrass varieties at both sites are offered in Table 1.1.4.

Table 1.1.1 Overwintered Switchgrass Spring 1999 Moisture Content and Yield

Variety	Moisture Content (%)		Yield (dry Mg ha^{-1})	
	Seedfarm	Ecomuseum	Seedfarm	Ecomuseum
Cave in Rock	12.3 a	13.5 a	6.6 a	7.1 a
Pathfinder	13.1 a	11.1 a	6.9 a	7.2 a
Sunburst	14.1 a	12.8 a	7.2 a	5.4 b
Average	13.2	12.5	6.9	6.6

Means with the same letter, within the same column, are not statistically different according to the SNK test (P=0.05).

The fall moisture contents (Table 1.1.2) were almost three times higher than in spring, because the crop has less time to shed its moisture compared to spring (when it overwinters). At the Ecomuseum, the Cave in Rock variety had significantly higher moisture content (53.8%), compared with 47.7% and 44.9% for Pathfinder and Sunburst, respectively. Sunburst and Pathfinder are early maturing varieties, and hence senesce sooner in fall and lose most of their moisture before Cave in Rock.

The yields did not differ significantly at the Seedfarm. At the Ecomuseum, Cave in Rock yields were significantly higher than Sunburst (13.6 compared with 9.8 Mg ha^{-1}, respectively), and Pathfinder did not differ from either. Cave in Rock is the latest maturing variety, followed by Pathfinder and then Sunburst, which is reflected in the fall yields at the Ecomuseum. As a result of

its late maturity, it captures solar radiation for a longer period during the growing season.

Table 1.1.2 Switchgrass Fall 1999 Moisture Content and Yield

Variety	Moisture Content (%)		Yield (dry Mg ha^{-1})	
	Seedfarm	Ecomuseum	Seedfarm	Ecomuseum
Cave in Rock	44.9 a	53.8 a	12.9 a	13.6 a
Pathfinder	41.1 a	47.7 b	10.9 a	12.1 ab
Sunburst	38.5 a	44.9 b	9.2 a	9.8 b
Average	41.5	48.8	11.0	11.8

Means with the same letter, within the same column, are not statistically different according to the SNK test (P=0.05).

A ratio of spring yields to fall yields showed the large switchgrass losses that occur (e.g. leaf fall, stem breakage, seed head loss) due to overwintering (Table 1.1.3). in past seasons, Cave in Rock has been more vulnerable to losses as the variety has a brittle nature compared to Sunburst and Pathfinder. These losses are considerably higher than in previous seasons which may have been due to a relatively mild winter.

Table 1.1.3 Switchgrass Overwintering Losses

From October 1998 to May 1999

Variety	Overwinter Losses (%)	
	Seedfarm	Ecomuseum
Cave in Rock	51.8	37.2
Pathfinder	47.7	41.0
Sunburst	39.5	49.5
Average	46.3	42.6

Table 1.1.4. Fall Switchgrass Yields from the Plantation Sites in

Ste-Anne-de-Bellevue, Quebec (1994-1999).							
Cultivar	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**Six-Year Average**
	odMg/ha						
Seedfarm Site							
Cave-in-Rock	9.7 ab	11.0	11.9 a	11.7	13.7	12.9	11.8
Pathfinder	9.9 a	10.9	11.3 b	11.6	13.2	10.9	11.3
Sunburst	8.8 b	9.5	10.9 b	12.0	11.9	9.2	10.4
Ecomuseum Site							
Cave-in-Rock	7.9	9.6	12.7 a	13.5	11.3	13.6	11.4
Pathfinder	7.4	9.7	11.3 ab	12.8	12.2	12.1	10.9
Sunburst	7.0	8.5	10.1 c	12.4	10.7	9.8	9.7
Average Yield	**8.5**	**9.9**	**11.4**	**12.3**	**12.2**	**11.4**	**10.9**

Means within a column followed by the same letter, or no letter, within a site are not significantly different at the 0.05 level according to Duncan's Multiple Range test.

Short Rotation Willow

The willow was harvested on November 1, 1999. No disease or pest incidences were noticed during the growing season. The yearly incremental *salix x alba glatfelteri* willow yields are presented in Table 1.1.4.

Table 1.1.5. SR Willow Moisture Content, Yield and Population

Site	Moisture Content (%)	Yield (dry Mg ha^{-1})	Population (trees/ha)
Seedfarm	42.2 a	19.4 a	8524

Ecomuseum	43.9 a	21.9 a	8772
Average	43.1	20.7	8648

Means with the same letter, within the same column, are not statistically different according to the SNK test (P=0.05).

In 1999, the willow at the Seedfarm had an average annual incremental growth of 19.4 Mg ha^{-1}, while at the Ecomuseum, the annual incremental growth was 21.9 Mg ha^{-1}. The sites were not significantly different from each other. Moisture contents were not significantly different either.

The crop also suffered from a late summer drought that caused more than 50% defoliation of the stand in September 1999.

In 1998, annual incremental yields were an average of 25.6 Mg ha^{-1} at the Seedfarm, and 15.3 Mg ha^{-1} at the Ecomuseum, although no statistical differences were found. In 1999, incremental yields were more even, due to less variability measured. The average incremental yield obtained (20.7 Mg ha^{-1}) is approximately the same as in 1998 (20.5 Mg ha^{-1}), which shows that yields are stabilizing, in the sixth year.

Population densities of SR willow were conducted on both sites, before coppicing, in December 1999 (Table 1.1.4). Populations at the Ecomuseum were higher than at the Seedfarm, by approximately 250 trees/ha. Although trees were planted at a density of 11 000 trees/ha in 1993, the survival rate of the SR Willow trees at the Seedfarm was 9 500 trees/ha, and 10 000 trees/ha at the Ecomuseum. The population density declined from 1993 due to self-thinning. However, the difference in population densities between the sites was still apparent, although narrowing.

Table 1.1.6. Short Rotation Willow Yields (odMg/ha)

From Plantation Sites in Ste-Anne-de-Bellevue, Quebec (1994-1999)

Site	**1994‡** **1st cycle**	**1995** **1st cycle**	**1996** **2nd cycle**	**1997** **2nd cycle**	**1998** **2nd cycle**	**1999** **2nd cycle**	**Six-Year Average**
	OdMg/ha						
Seedfarm†	4.4	11.6	6.6	7.2	25.6	19.4	12.5
Ecomuseum	9.4	8.8	7.6	9.6	15.3	21.9	12.1
Average	6.9	10.2	7.1	8.4	20.5	20.6	12.3

‡ Total increment for 1993 and 1994.

† Does not include block 4

Means within a column followed by the same letter, or no letter, are not significantly different at $P>0.05$ level according to Duncan's Multiple Range test.

Corn

The corn was harvested on September 28, 1999 (Table 1.1.5). The corn had average grain yields of 9.3 Mg ha^{-1} at the Seedfarm, and 9.5 Mg ha^{-1} at the Ecomuseum. The total grain and stalk yields at the Seedfarm were 16.7 Mg ha^{-1}, while at the Ecomuseum they were 16.8 Mg ha^{-1}. No significant yield differences between the sites were found. The moisture contents were not significantly different, despite the large differences.

Table 1.1.7. Corn Moisture Content and Yield

Site	Moisture Content (%)	Grain Yield (dry Mg ha^{-1})	Grain+Stalk Yield (dry Mg ha^{-1})
Seedfarm	23.9 a	9.3 a	16.7 a
Ecomuseum	38.2 a	9.5 a	16.8 a
Average	31.1	9.4	16.8

Means with the same letter, within the same column, are not statistically different according to the SNK test (P=0.05).

In 1998, the grain corn yields were 7.8 Mg ha^{-1} and 8.1 Mg ha^{-1} at the Seedfarm and Ecomuseum, respectively.

Table 1.1.8. Corn grain yields from plantations sites in Ste-Anne-de-Bellevue, Qc (1996-1999)

Site	**1996[a]**	**1997[b]**	**1998[c]**	**1999**	**Average of 1996, 1998, 1999**
	od/Mg/ha				

Seedfarm Site	8.6	5.9	7.8	9.3	8.6
Ecomuseum Site	8.3	n.a.	8.1	9.5	8.6
Average	**8.5**	**n.a.**	**8.0**	**9.4**	**8.6**

[a] Hybrid Pioneer 3921

[b] Hybrid Pride K206

[c] Hybrid Pioneer 3893

n.a., not available because of pest damage

Means within a column followed by the same letter, or no letter, are not significantly different at the 0.05 level according to Duncan's Multiple Range test.

Comparisons Between Crops

Both the short rotation forestry willow and switchgrass continue to maintain high production levels with modest fertilization rates. The willow growth in 1999 continued the outstanding growth that was first demonstrated in the stands in 1998 with annual production levels of 20 ODT/ha. These two consecutive years of high yielding crops are making SRF willow a more viable bioenergy crop than suggested in earlier research reports derived from the sites. High yields are critical to reducing feedstock production costs. The six-year mean yields of these two crops are now 11.6 Mg/ha for Cave-in-Rock switchgrass and 12.3 Mg/ha for Salix alba x glatfelteri willow. This compares favourably with the grain corn at 8.6 Mg/ha. Further assessment of willow yields in the next coppicing cycle will provide additional information on making more accurate productivity estimates for Eastern Canada. Switchgrass production estimates are rather consistent between years. However overwintering losses appeared quite high in 1999. These high losses may indicate that this strategy should be best utilized for high value markets such as pulp and paper or as a means to regenerate weakened stands of switchgrass that may occur from fall harvesting

2. Farm Scale Switchgrass Plantation at St. Timothée, Qc

The site at St. Timothée is located at M. Norman Caron's farm in Valleyfield, 40 km southeast of Montreal. The site consists of 6 hectares of Cave in Rock switchgrass, seeded in June 1995, at a rate of 10 kg ha^{-1}. In 1999, the site was fertilized with 60 kg N ha^{-1}. Spring sampling was conducted on April 29; fall harvesting took place on September 29, 1999. The harvestable biomass was estimated by hand harvesting 15 randomly placed 1 m^2 sampling quadrants. The stand was highly productive, and showed very promising yields of 8.3 Mg ha^{-}

^{1} in spring and 12.7 Mg ha^{-1} in fall (Table 1.2.1). No pest or disease incidences were noticed during the growing season.

Table 1.2.1 Spring and Fall Switchgrass Yields, St. Timothée

Sample	Spring	Fall
	Dry Yield (Mg ha^{-1})	
1	8.2	12.6
2	9.8	14.2
3	7.6	14.1
4	7.9	15.2
5	8.4	15.3
6	10.1	11.3
7	8.1	12.3
8	9.8	10.1
9	8.4	14.6
10	8.0	12.6
11	9.1	12.2
12	8.7	6.8
13	8.2	11.9
14	6.6	15.8
15	5.2	12.0
Average	**8.3**	**12.7**

In 1998, the spring yields were 7.6 Mg ha^{-1}, and in fall they were 10. 5 Mg ha^{-1}. Four years after seeding, the site is approaching full establishment, this means the stand has a higher competition against weeds, and the yields are expected to stabilize hereafter.

The spring 1999 yields were above average for what was obtained for Cave in Rock at the Ste. Anne de Bellevue plantations after six years (Table 1.1.1), and fall yields were also

higher (Table 1.1.2). The climate and soil type in the region is well suited for switchgrass. The site is weed free and has a good drainage capacity with little unevennesses.

As a comparison, at the second commercial site, in Berwick, Ontario, spring yields, four years after seeding, were 9.0 Mg ha^{-1} and fall yields were 11.9 Mg ha^{-1}. These yields are very comparable to those obtained at St. Timothée.

Conclusion

Switchgrass is highly productive in regions with CHU of 2500, when grown on well-drained sites. The site in St. Timothée demonstrates a strong vigorous stand that has reached establishment four years after seeding. Although weed pressure may be inhibitory for establishment, switchgrass tends to out compete weeds within the 3rd growing season, as was observed at the Rutley Farm in Berwick, Ontario.

Task 2: Variety Selection and Plant Improvement Program

2.1. Miscanthus Evaluation Trial

The Miscanthus experiment was arranged in a randomized complete block design with 4 blocks, and 2 treatments in each block. Individual plot sizes measured 5m by 5m. The miscanthus was transplanted into the plots in June 1995. From 1995 to 1998, fertilizing consisted of applying 60 kg ha^{-1} of N in all plots. In 1999, the treatments consisted of two levels of N fertilizer; 50 kg ha^{-1} and 100 kg ha^{-1} (two treatments in each block). The plots were fertilized on June 9 with ammonium nitrate (34-0-0). Agronomic data was obtained on heights and yields to determine if there was a fertilizer treatment effect.

The soil was a St. Bernard loam, in the 0-20 cm depth horizon, the < 2 mm mineral fraction consisted of 50 % sand, 27 % silt, 23 % clay. These soils are well drained and have a 0-15 cm A horizon. The pH was found to be 6.7, and the organic matter varied from 6.2 to 4.9 % (Table 2.1.1).

Table 2.1.1 Soil Analysis for Miscanthus Plots from 0-20 cm

pH	P	K	Ca	Mg	O.M.
	mg kg^{-1}				%
6.68	27.2	164	2215	404	6.2-4.9

Spring yields were obtained on May 7, by hand harvesting three 1-m^2 quadrants in each plot. No treatment differences were observed (Table 2.1.2). In fall, a Jerry mower was used to harvest the miscanthus, on October 25. This method allowed a greater area (approximately 4-5 m^2) in each plot to be harvested in a shorter amount of time. No difference between the treatments was found in fall either (Table 2.1.2).

Table 2.1.2. Moisture Contents and Dry Matter Yields for Miscanthus

Treatment	Moisture Content (%)		Dry Yields (Mg ha^{-1})	
	Spring	Fall	Spring	Fall
50 kg ha^{-1}	13.5 a	36.8 a	6.8 a	9.3 a
100 kg ha^{-1}	12.7 a	40.3 a	5.7 a	8.3 a

Means with the same letter, within the same column, are not statistically different according to the SNK test (P=0.05).

Miscanthus fall yields were comparatively lower than switchgrass yields (fourth year plantation fall switchgrass yields were 12.3 Mg ha^{-1}, compared with approximately 9 Mg ha^{-1} for miscanthus). In milder and wetter climates (i.e. England), miscanthus tends to have greater biomass potential. Other varieties of Miscanthus may provide more productive yields. This clone was sourced from material being sold in the ornamental nursery trade.

Spring heights taken on June 18, showed no statistical differences. The 50 kg ha^{-1} treatment had average heights of 123.2 cm, whereas the 100 kg ha^{-1} treatment had average heights of 128.0 cm.

Lodging measured on a scale from 1-10 (1 being the least lodged) on October 25, showed no difference between the 50 kg ha^{-1} and 100 kg ha^{-1} treatments.

2.1.1 Conclusion

Rates of 50 kg N ha^{-1} are sufficient for miscanthus production in these climates and soil types, without any adverse pest or disease incidences noticed. As well, no differences in heights or lodging were observed in the 50 kg N ha^{-1} compared with the 100 kg N ha^{-1} treatment. Although yields were not greater than switchgrass yields, in wetter climates miscanthus has outperformed switchgrass.

2.2. Switchgrass Variety Trial – Pintendre, Qc

A variety trial was established in Pintendre, Quebec, on the farm of Mr. Marcel Labrie, in May 1998. Mr. Labrie is a dairy farmer and cash crop grower, who is exploring the possibility of growing alternative crops. Pintendre is located east of Quebec City. It is the coolest site in eastern Canada to have assessed swithgrass. This variety trial aims to evaluate the adaptation of different varieties in cooler regions.

The soil is a well drained, loamy sand. Seven varieties were seeded on May 27, 1998 at a rate of 7 kg/ha; Cave in Rock, Sunburst, REAP 921, REAP 922, Pathfinder, Blackwell and Forestburg. Each plot measured 4 m by 5 m. The treatments were arranged in a randomized complete block design (RCBD), with four blocks.

The site was ploughed in autumn and tilled the following spring, before seeding. An application of 2 L ha^{-1} of Laddock was applied one month after seeding, A field visit in the fall of 1998 evaluated the progression of the switchgrass, including any weed or insect incidences.

In 1999, a visit was made to the site on May 22. The stand was not harvested due to the minimal standing biomass, instead, the biomass was left as straw. Only a few varieties (the most promising) were harvested for yield determination (Table 2.2.1). Some hand weeding and fertilization was carried out on May 22, with 60 kg N ha^{-1}. Light incidences of quackgrass were noticed in some plots. No insect pressure was noticed.

Table 2.2.1. Spring Yield Evaluation in 1999 for Certain Varieties

Variety	Spring 1998 Yield
	Mg ha^{-1}
Cave in Rock	0.59
Pathfinder	0.71
REAP 922	0.13
Sunburst	0.27

Average	0.43

Despite the low yield evaluations, the stand evaluation on May 22, for Cave in Rock was excellent, for Pathfinder it was very good, that of Sunburst and REAP 922 was good, whereas that of REAP 921 was poor. Blackwell and Forestburg had no standing biomass.

Heights were also obtained in 1998 (Table 2.2.2), as a measure of establishment. The Cave in Rock variety had the tallest stand, whereas Blackwell had the shortest stand. Lodging rates indicated Cave in Rock to have the least lodging, and Blackwell to have the most (Table 2.2.2).

Table 2.2.2 Average Height of Switchgrass in Spring 1998

Variety	Height	Lodging
	(cm)	(scale of 0 to 10)
Cave in Rock	88.1 a	0
Pathfinder	81.4 ab	1
REAP 922	72.4 b	5
REAP 921	56.1 cd	9
Sunburst	69.1bc	7
Forestburg	55.4 cd	8
Blackwell	52.7 d	10
Mean	**67.9**	**5.7**

Means with the same letter, within the same column, are not statistically different according to the SNK test (P=0.05).

The fall yields were obtained on October 27 (Table 2.2.3). Half of each plot was harvested using a Jerry mower. The samples were weighed and a subsample was obtained for measuring moisture content. Lodging rates were also measured (Table 2.2.3).

Table 2.2.3. Fall 1999 Yields, Moisture Content and Lodging

Variety	Yield	Moisture Content	Lodging
	(Mg ha^{-1})	(%)	(scale of 0 to 10)
Cave in Rock	9.9 a	33.0 a	0.5 a
Pathfinder	6.9 b	30.6 a	3.0 a
REAP 922	6.1 b	29.2 a	1.0 a
Forestburg	4.9 b	28.7 a	2.0 a
Sunburst	4.7 b	31.9 a	2.5 a

Means with the same letter, within the same column, are not statistically different according to the SNK test (P=0.05).

The REAP 921 and Blackwell varieties did not establish during the 1998 season, and therefore, were omitted from the sampling in 1999. Low quality seed led to the poor stand establishment.

Among the varieties that established, Cave in Rock had a significantly higher yield of 9.9 Mg ha^{-1}, compared to the other varieties (Table 2.2.3). The other four varieties were not significantly different from each other and had yields ranging from 6.8 Mg ha^{-1} (Pathfinder) to 4.7 Mg ha^{-1} (Sunburst). Contrary to the yields, no difference in the moisture content was noticed.

Lodging rates showed Cave in Rock to have the least lodging, followed by REAP 922, Forestburg, Sunburst, and Pathfinder. However, statistically, no difference was found (Table 2.2.3). Lodging did not appear to be a problem for any of the varieties and cannot help to explain the difference in yields obtained.

Some disease was observed on all varieties except Cave in Rock, which had very little blackening. The disease was a form of rust. Selecting a rust resistant variety is important to ensure maximum production. The Cave in Rock appeared to be relatively resistant to rust while other materials were hit by the rust outbreak. This likely contributed to the superior yields obtained by the Cave in Rock variety. The site is located near the St Lawrence River and tends to receive more dew and fog than other locations. This may have contributed to the high incidence of rust observed at this site.

Conclusion

With dry yields of 10 Mg ha^{-1}, Cave in Rock had excellent biomass production for the first year and proves that switchgrass can be suitable to grow in similar regions and soil types. However, it must be noted that the region received 2912 CHU, which is 253 CHU above the

normal. Cave in Rock also appeared to be fairly resistant to the rest, which affected most of the other varieties.

3.0. Summary and Conclusion

The study indicated that in 1999, in southwestern Quebec, SR willow aboveground productivity exceeded switchgrass and corn productivity, at both sites. A stabilization in the SR willow annual incremental yields was noticed at approximately 20 Mg ha^{-1}, averaged for both sites. Switchgrass yields for the check variety Cave-In-Rock switchgrass were 13 Mg/ha in fall. Yield losses of overwintered material were high in 1998-1999 with losses of 44%. Corn grain yields averaged 9.4 Mg ha^{-1}. Once established, bioenergy crops have the potential to have higher productivity than corn.

Switchgrass demonstrated high productivity at two other locations in Quebec; St. Timothée, and in Pintendre, which is the most northerly located site. The site in St. Timothée is approaching full stand establishment, after four years, with yields peaking in 1999 at 12.7 Mg ha^{-1}. In Pintendre, after the first growing season, an excellent first year production of 9.9 ODT/ha was obtained from Cave-in-Rock switchgrass. Most of the other varieties are equally well established, but had lower yields. This appeared to be mainly attributed to the incidence of rust.

Miscanthus was evaluated at Ste Anne de Bellevue, Quebec as another potential perennial bioenergy crop. Yields in the fourth season were found to be approximately 9 Mg ha^{-1} for both the 50 kg ha^{-1} and 100 kg ha^{-1} treatments.