SWITCHGRASS Agronomy

2016

ONTARIO BIOMASS PRODUCERS CO-OPERATIVE INC.

for a cleaner tomorrow

By R. Samson, E. Delaquis, B. Deen, J. DeBruyn and U. Eggimann

Acknowledgements

This document was developed with the support of:

OMAFRA-U of G Knowledge Translation & Transfer Program

Agri-Food and Rural Link
A program of the OMAFRA – U of G Partnership
Mobilizing Agri-Food and Rural Research Knowledge

Livestock Research Innovation Corporation Inc.

LRIC LIVESTOCK RESEARCH INNOVATION CORPORATION

Ontario Agri-Food Technologies

Ontario Agri-Food Technologies
from discovery to profit

Ontario Biomass Producers Co-operative Inc.

ONTARIO BIOMASS PRODUCERS CO-OPERATIVE INC.
for a cleaner tomorrow

[TABLE OF CONTENTS]

The Ontario Biomass Producers Co-op would like to thank the document developers for their work toward the creation of this document.

Roger Samson M.Sc
REAP-Canada

Erik Delaquis M.Sc
REAP-Canada

Bill Deen Ph.D
University of Guelph

Jake DeBruyn P.Eng
Ontario Ministry of Food, Agriculture and Rural Affairs

Urs Eggimann
Eggimann Farms

The Ontario Biomass Producers Co-op would also like to acknowledge the efforts of the following individual contributors, in alphabetical order:

Gary Bergstrom
Cornell University

Mike Cowbrough
Ontario Ministry of Agriculture, Food and Rural Affairs

James Fisher
Fidale Farms

Patrick Huber-Kidby
Ontario Ministry of Agriculture, Food and Rural Affairs

Olivier Lalonde
Centre de recherche sur les grains

John Molenhuis
Ontario Ministry of Food, Agriculture and Rural Affairs

Don Nott
Switch Energy Corp

Mahendra Thimmanagari
Ontario Ministry of Food, Agriculture and Rural Affairs

Kate Withers
Ontario Centres of Excellence

[TABLE OF CONTENTS]

Table of Contents

Table of Figures

Switchgrass Basics

Introduction

This agronomy basics book provides a summary of research and practical knowledge about growing and harvesting switchgrass. It is designed for farmers to get a basic understanding of the latest knowledge and experience from Ontario and other relevant jurisdictions. Funding partners who sponsored this book are listed on the cover.

What Is Switchgrass?

Switchgrass (*Panicum virgatum L.)* is a North American native perennial warm-season grass. Switchgrass is one of the most promising species of biomass crops in Ontario. Along with big bluestem and Indiangrass, it is one of the three dominant species of the North American tallgrass prairie. In its native habitat, switchgrass is generally found in the more humid zones of the tallgrass prairie. It is a well-adapted species to Ontario's conditions that can still be observed on protected lands of southern and central Ontario. The native range of switchgrass in Canada is from southeastern Saskatchewan to central Nova Scotia.

10 Key Points in Switchgrass Production

1. Site Selection and Preparation: Switchgrass is easiest to establish on well drained soils that have previously been used for annual cropping. If the site is converted from long term perennial forages, make sure the perennial weeds are thoroughly killed in the late summer/ early fall of the previous year.

2. Seed Source: First time growers should source high quality seed of the Cave-in-Rock variety and plant at least 10kg/ha.

3. Seeding: On conventionally tilled soils use of a Brillion seeder works well. No-till establishment can give equally good results. Make sure you pack the fields before and after planting.

4. Use of a Nurse Crop or Direct Seed: In Southern Ontario it is likely best to undersow switchgrass in spring wheat. A broadleaf herbicide can be used for broadleaf weed control in the cereals. In cooler zones <2400 CHU, it is likely best to direct seed the crop and use atrazine pre-emergence.

5. No First Year Harvest: Do not harvest the switchgrass crop in the fall of the seeding year to ensure good winter survival

6. Fertilization: Switchgrass does not generally require fertilizer in the seeding year. In all subsequent years, switchgrass can be fertilized with 60-70 kg N/ha (50-60lbs/acre) in late May or early June. Switchgrass will generally not respond economically to lime, phosphorus or potassium fertilization unless soil tests indicate levels are very low.

7. Mowing: The crop is cut with a discbine in the fall after the first killing frost to a 10cm stubble height and laid into a swath.

8. Raking: In spring the crop is commonly raked into a windrow to promote drying and baled as soon as drying conditions permit.

9. Baling: Most farmers producing switchgrass for sale will bale into large square bales for off-farm transport. Farmers growing switchgrass for on-farm use likely will find round baling to be the most economic.

10. Storage: Square bales can be stored for longer periods in storage sheds or under plastic tarps for shorter periods. Outdoor storage of net-wrapped round bales on a crushed gravel pad is a good option for on-farm use.

Figure 1. The two most promising native grasses for biomass production in Ontario are big bluestem (left) and switchgrass (right). Research trials of adapted cultivars of these species have produced similar yields in Ontario. Compared to big bluestem, switchgrass is easier to establish, faster to come into full production and has more tolerance of wetter soils. Some trials in the US have found favourable results by planting the two species in a mixture.

Why Grow Switchgrass?

Switchgrass is a farmer-friendly crop with exciting market opportunities. It requires low investment and minimal labour. In Ontario, switchgrass has been successfully grown on both prime agricultural land and on more marginal class 3 soils that are stony, gravelly or relatively shallow. It is relatively easy and inexpensive to establish from seed, and can be grown and harvested using conventional farm equipment. Switchgrass is cut once per year, and is harvested off-season from other baling activities.

Figure 2. The first field scale plantation of switchgrass in Ontario was planted at the farm of Rick Rutley of Berwick, Ontario in 1997.

In Southern Ontario farmers are achieving dry matter yields of 7-12 t/ha (3 to 5 tonnes per acre). Markets are developing as more farmers learn ways to use switchgrass. Currently farmers are selling switchgrass as a premium replacement for straw into markets including livestock and poultry bedding, dairy cattle feed, and mushroom composting. Switchgrass has great environmental qualities, including locking up carbon in its roots, reducing runoff of agricultural nutrients and topsoil, and contributing to bird and pollinator habitat.

Figure 3. Halton Region farmer Jamie Fisher standing with a spring harvested bale of switchgrass biomass. The newly emerging crop has already commenced green-up.

History of Switchgrass in North America

Switchgrass was domesticated in the 1940s in the U.S. as a mid-summer forage and erosion control species. It is mainly used for grazing in the south-central states. In the 1990s, it was widely planted in the U.S. conservation reserve program for its erosion control and wildlife planting value. A main advantage of switchgrass as a grazing species is that, as a warm-season grass, it grows well in the hot, dry summer months. It fills in the mid-summer grazing gap that commonly occurs with cool-season grasses. As a conservation species, switchgrass is inexpensive to seed and relatively easy to establish compared to other prairie grasses. It provides excellent cover and is less prone to lodging than almost all other prairie grasses. Its use as a fodder crop has been slow to develop,

as switchgrass tends to have low crude protein and digestibility, and animal rates of gain and intake are modest.

Why Switchgrass Is a Promising Biomass Crop

Due to its perennial nature, good productivity and ease of growth, switchgrass was one of many candidate biomass crop species tested by the U.S. Department of Energy in the 1980s. These tests across the various regions of the U.S. identified switchgrass as a promising species in all major cropland areas, including the Great Lakes region and the northeastern states. It was found to have a moderate-to-high level of productivity, good adaptation to marginal farmlands and low cost of production. Switchgrass was chosen by the U.S. Department of Energy as its model herbaceous energy crop, which helped accelerate its commercialization as a biomass crop. Several of the most important traits of switchgrass are its ability to thrive on low-quality cropland, its drought tolerance, comparatively stable crop yields, its low fertility requirements and its longevity as a perennial.

A key advantage of switchgrass is that it utilizes the C_4 photosynthetic cycle like other warm-season crops, including corn, sorghum and sugarcane. Under optimal conditions, C_4 plants convert solar energy 40% more efficiently than C_3 crops (e.g., wheat and timothy) and use 50% less water for each tonne of biomass produced. Water availability is typically the most limiting resource affecting biomass yields in Ontario. Switchgrass is a very good biomass producer as it has a deep root system to extract water from the soil, which is then used twice as efficiently as C_3 plants. Switchgrass also can have great longevity, with some stands in Ontario and Quebec exceeding 15 years of production.

Environmental Benefits

Switchgrass can provide numerous benefits to the environment, compared to annual field crops. Noteworthy impacts of switchgrass stands are their ability to reduce erosion, protect surface water quality, increase soil carbon and aggregate stability, and encourage biodiversity. Soil erosion will be largely eliminated by switchgrass cultivation on most soil types in Ontario.

Surface phosphorus (P) runoff is also largely eliminated as sediments are trapped in the field stubble and residues. P fertilizer is generally not used, so the potential for surface P runoff is reduced. Groundwater nitrogen contamination is minimized as the crop has low N demands (typically 60 kg N/ha) relative to field crops, and the deep perennial root system prevents leaching of nitrogen below the rooting zone.

Switchgrass is being used successfully as a buffer strip to help reduce sediment, nutrient and pesticide runoff from adjacent cropland. It provides excellent surface cover in all seasons and promotes rapid water infiltration. Depending on site conditions, a 10-m buffer strip receiving uniform flow over its width can trap between 50% and 90% of the sediment load contained in the runoff water it filters. Established switchgrass stands will infiltrate water into the soil approximately five times faster than annual field crops. The root mass of switchgrass helps create a soil with low bulk-density under the crop, an important characteristic that can help enhance the groundwater recharge of watersheds.

Switchgrass and other native perennial tallgrasses have created the most carbon-rich soils in North America. Switchgrass increases soil carbon storage both through its large root system and through annual carbon additions to the soil by leaf drop and root carbon additions. Typically, about 25% of the root system turns over each year to contribute to soil carbon additions. Overall warm-season perennial grasses are unsurpassed in their ability to increase soil organic matter levels in field crop production.

Switchgrass cultivation can contribute to the restoration of biodiversity on farmlands. The biodiversity of switchgrass fields is considerably better than croplands subjected to annual cropping. A perennial native grass agroecosystem is a less intensively manipulated production system with minimal annual disruption through tillage and pesticide use.

Figure 4. Large fields of switchgrass (50 acres+) are preferred by grassland specialist birds to minimize nest predation. Switchgrass fields managed for biomass appear to be particularly valuable for increasing savannah sparrow and grasshopper sparrow populations.

Bird surveys have found that greater populations of birds are present in switchgrass fields, including important grassland birds that are in decline in Ontario, such as grasshopper sparrow, savannah sparrow, dickcissel and bobolinks. Switchgrass is a perennial crop that is generally harvested in a period when birds are not actively nesting. Mowing the material in the late fall and harvesting in early spring generally does not overlap with the reproductive cycles of insects or birds. Another advantage to bird populations from nesting in switchgrass fields is that there is a lower predation rate than in row crops, due to the difficulty predators have locating nests. Insect life is both more abundant and diverse in switchgrass fields. In particular, this helps support insect-eating

populations of birds in decline, such as swallows. The seed of switchgrass can be an important food source for sparrow species.

Another major advantage of switchgrass fields is that they support important populations of wild pollinators. A diversity of flowering perennial plants exists in switchgrass fields, especially those growing on marginal farmlands. Species such as wild carrot, goldenrod, Canada fleabane, milkweed and purple vetch commonly invade older switchgrass fields and provide considerable food and habitat for insect and bird populations. A study in the Great Lakes region found that when compared to corn, switchgrass fields provided a higher abundance, species richness and diversity of beneficial insects than corn fields.

Figure 5. On marginal farmlands and in older stands, switchgrass "monocultures" are seldom seen. A diversity of flowering legumes and forbs are present in stands that help support birds and wild pollinators. Common "weeds" of switchgrass stands formerly in hay and pasture crops include purple vetch, alsike clover, bromegrass, goldenrod, dandelion and Canada fleabane.

Some farmers will want to make extra efforts to support biodiversity in their switchgrass fields. Biodiversity is best supported through the establishment of large fields, use of grass mixtures (such as the inclusion of big bluestem) and creation of more heterogeneity in the field — creating a more diverse landscape for species so they can choose their preferred environment for feeding and nesting. For example, farmers can leave strips of their fields uncut and cut the field at different heights to improve nesting opportunities for some grassland bird species.

Finally switchgrass can have tremendous benefits to aquatic life. It largely eliminates soil and nutrient runoff into water courses. As a field buffer strip its deep root system can help mitigate nitrate flow into adjacent water courses. Pesticide runoff is also minimized into water courses as insecticides are not used on the crop and herbicide use is limited mainly to the establishment years. Overall, switchgrass has many positive benefits for the environment compared to field crops that require much more intensive and environmentally taxing cultivation practices.

Site and Material Selection

Site Selection

Switchgrass has been shown to grow very well on high quality field crop land (Class 1 and 2), but is also capable of achieving good yields on lower quality lands that are not well suited to field crop production. Marginal Class 3 lands in Ontario can be a good choice for switchgrass as few crops can be grown profitably on these soils due to low yields and increased risk of crop failure.

Figure 6. Urs Eggimann stands in late June beside a well-established stand of switchgrass on marginal Class 3 stone-filled land near Markdale, Ontario.

Experience in Ontario indicates that switchgrass is easier to establish on well-drained loam and sandy soils than on clay soils. Several problems may be experienced by growers who get poor stands on poorly drained clay soils. Switchgrass seed is fairly small, and seeds can have great difficulty emerging on heavy clay soils, which lack air spaces to make the journey upwards easier for emerging seedlings. Roots of young seedlings also have difficulty penetrating into clay soils. As well, clay soils are also usually slower to warm up in the spring, which delays growth.

Switchgrass grows best on well-drained soils (surface and/or tile drainage). These soils generally have better establishment and tend to have reasonably dry soil conditions for harvest operations. Due to the extensive root system and perennial nature of switchgrass, good productivity can often be achieved on medium to lower-fertility soils where annual field crops have low profitability. Coarse or gravelly soils, stone filled farmlands and south-facing slopes in Ontario are good field choices for switchgrass as few other crops can be grown successfully in those difficult field conditions. Yields may be lower on coarse soils in dry years due to moisture availability issues.

Well-drained heavy clay soils can also produce excellent switchgrass yields. Well-drained heavy clay soils are generally more productive than lighter soils, as they provide more water to the crop in the mid-summer period when coarse soils get excessively dry. Growers in Southern Ontario may be quite successful growing switchgrass on clay soils that are often prone to late planting problems for field crops.

Many growers in Eastern Canada are choosing to grow switchgrass in the cooler production zones of Ontario and Quebec that produce modest row crop yields. On well drained soils, switchgrass can be a relatively good producer in the 2100-2700 Corn heat units (CHU) areas in these provinces. Figure 6 indicates the 2100-2700 CHU zones in the pale to deep yellow areas.

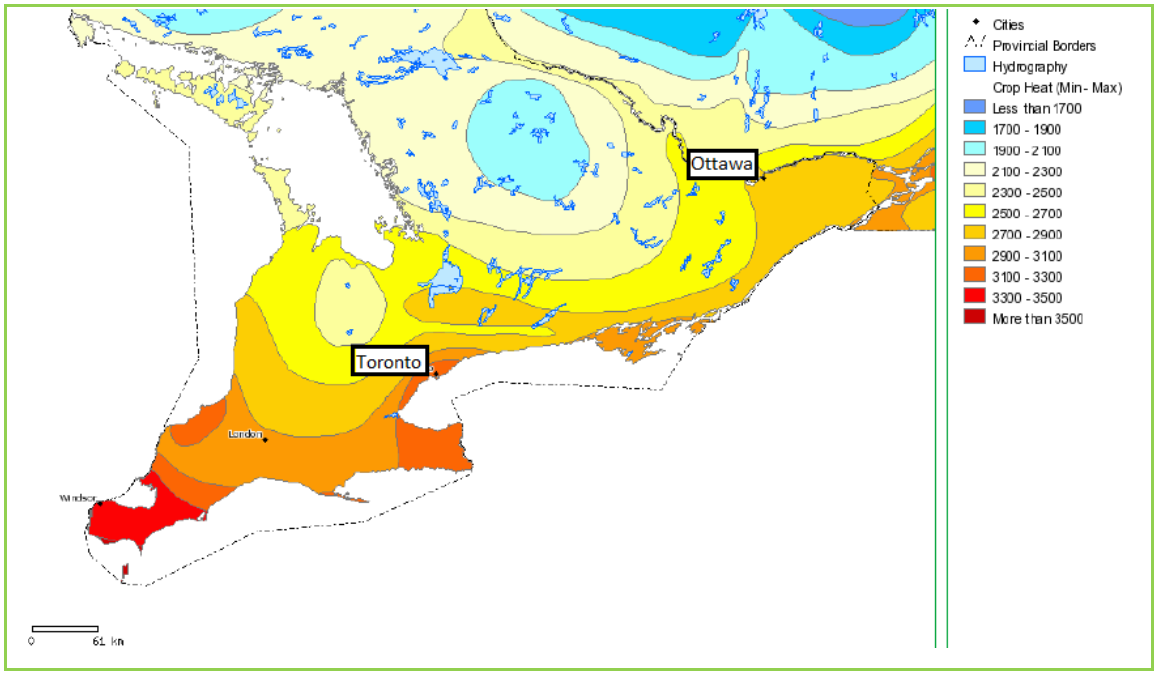

Figure 7. Promising target areas for switchgrass production are marginal class 3 lands throughout Ontario and the cooler production zones of 2100-2700 CHU areas.

Types of Switchgrass

Switchgrass ecotypes are divided into two broad categories: *lowland* and *upland*. Lowland ecotypes evolved under floodplain conditions, while upland ecotypes developed under drier upland sites. In Ontario, all the native switchgrass found in the province is of the upland type, since the lowland ecotypes are less winter hardy.

Lowland ecotypes have winter survival challenges mainly due to their crowns being found at the soil surface, much like alfalfa. Upland switchgrass has all its living components below ground during winter, making it much less sensitive to injury. Seed of upland switchgrass can be double the seed weight of lowland switchgrass making it less expensive to seed and easier to establish. Native lowland switchgrass is generally taller and has more erect leaves and thicker stems than native upland varieties. Lowland switchgrass also has smaller seeds and is more difficult to establish than upland switchgrass.

The high yield of lowland switchgrass appears to be due to its later maturity, high stem component and more erect canopy structure. In eastern North America, breeders are now developing upland switchgrass varieties with a more erect canopy, fewer tillers and later maturity to obtain higher yields.

Figure 8. Plant breeders are developing improved selections of upland switchgrass for specific high yield traits including erect leaf architecture, late flowering, increased height, high leaf to stem ratio and a reduced number of stems .

Figure 9. Research trials in Ontario and Quebec have identified several newly developed switchgrass cultivars with improved yield and agronomic performance. These cultivars are presently being scaled up in Ontario by members of the Ontario Biomass Producers Cooperative. This photo shows different yield outcomes at a research plot.

Choosing a Switchgrass Variety

In Ontario the main selection of switchgrass used by farmers has been Cave-in-Rock. This upland variety has shown good establishment, good winter tolerance, high yields, and suitability on a variety of soil types. New varieties under development by REAP-Canada, include selections and synthetic lines developed from Cave-in-Rock, Summer, Sunburst, and High Tide. These new materials have more rapid establishment, higher yields, less lodging and better adaptation to wet soils.

There are a number of factors that should be taken into consideration when choosing a switchgrass variety. Late season maturing switchgrass cultivars out-yield early maturing cultivars as they make more efficient use of the available solar energy during the growing season (Figure 10). Biomass researchers have

generally found that productivity is optimized in a given area when more southerly native germplasm is introduced approximately 300 km (200 mi) north of its site of origin. The most popular cultivar of switchgrass grown in Ontario is Cave-in-Rock. It was developed in 1959 from several plants found in a native prairie in southern Illinois. Cave-in-Rock is quite hardy in Ontario but in cooler zones (<2400 CHU) it may suffer winter injury in particularly cold years.

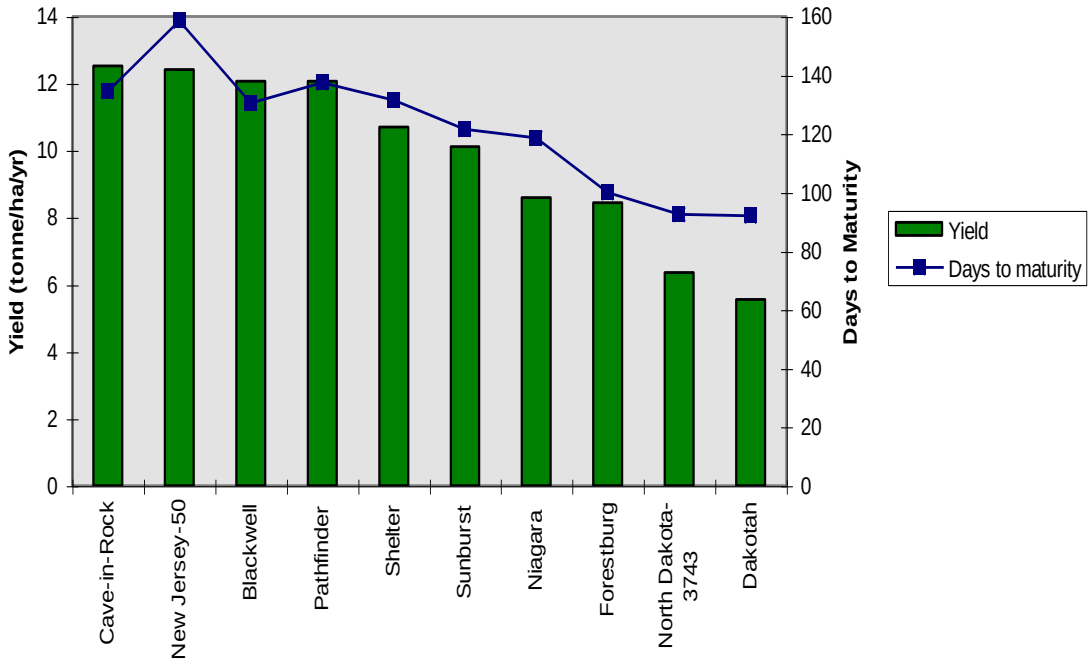

Figure 10. Yield (oven dry tonnes/ha) and maturity of switchgrass cultivars at Ste. Anne de Bellevue, Quebec (1993–96).

The desired time of mowing and/or harvesting will also affect the choice of cultivar. A late summer/early fall harvest may be desired by some producers. It may be appropriate to use an earlier maturing cultivar than Cave-in-Rock if a fall harvest is planned each year. Upland cultivars are generally very hardy in Ontario but they can suffer winter damage if harvested early. Switchgrass is similar to alfalfa in that it must be properly managed to ensure it enters winter with adequate carbohydrate reserves stored in its roots and crown. If underground root carbohydrates are depleted, winter hardiness can be reduced. A late-

maturing lowland switchgrass variety can easily be killed in Ontario if it is cut too early in the fall before it replenishes its winter nutrient reserves. Lowland varieties must be allowed to go fully dormant (i.e., be left in the field several weeks after the first killing frost) before cutting the crop. Established stands of upland switchgrass will seldom experience winterkill in Ontario. The main overwintering problem growers experience with upland switchgrass is thinned stands and reduced yields after winter stress.

Lowland Varieties

There has been some success with lowland switchgrass in the southern zones of Ontario where winter temperatures are less severe (i.e., above -25°C). Lowland switchgrass is at high risk of winterkill in the first year when plants are small. To minimize risks, lowland switchgrass producers should plant in winter hardiness zone 6b (i.e., southwest of London, Ontario) or warmer, and plant a hardier lowland cultivar such as Kanlow. Growers can also mix Kanlow with upland cultivars such as Cave-in-Rock or Carthage to minimize risks. Research in the US Midwest has found that upland-lowland switchgrass mixtures generally have very good yield performance and yield stability. Some breeders in the Midwest have also been crossing lowland switchgrass with upland switchgrass in an effort to improve both productivity and hardiness. This may eventually prove effective, but no cultivars suitable for Ontario have been developed to date with these types of crosses.

Upland Varieties

Most upland switchgrass cultivars perform well across southern, central and eastern Ontario. They have had few problems with winter hardiness when the crop is cut in a dormant state in late fall after the first fall frost. There is limited experience growing switchgrass in the clay belt of northern Ontario or in northwestern Ontario. Grower experience in Quebec has been very good on well-drained soils in the 2,000–2,200 CHU areas. It would be risky to grow switchgrass on soils with poor-to-imperfect drainage in northern regions of Ontario. The soils

in northern production zones can remain cool late in the spring, which doesn't favour the growth of warm-season grasses. Farmers should be especially careful about site location to be successful in switchgrass cultivation at northern locations.

Presented in Table 1 is a list of the most promising switchgrass cultivars currently available in Ontario. Most growers in Ontario grow Cave-in-Rock, as it is well adapted to the province and suitable for a variety of soil drainage conditions. Selections originating in the West tend to experience more disease pressure in Ontario. Farmers southwest of London, Ontario may consider trying smaller acreages of later maturing cultivars than Cave-in-Rock such as Carthage and Kanlow. These cultivars can also be mixed with Cave-in-Rock to ensure good winter hardiness.

The main problem with small seeded cultivars like Kanlow and Summer is the risk of poor stand emergence especially on heavy clay soils. Farmers with marginal lands should consider using larger seed cultivars to improve chances of good stand establishment. Farmers in northern and north western Ontario might consider using earlier maturing cultivars than Cave-in-Rock.

Table 1.
Key characteristics of some promising switchgrass cultivars in Ontario

Type of Switchgrass and Cultivar	+/– Days to Maturity Relative to Cave-in-Rock	Seed weight	Origin	Special Comments
Lowland				
Kanlow	+19	85 mg/100 seeds	Kansas	Lowland ecotype, high stem component, some winter hardiness concerns
Upland				
Carthage	+10	148 mg/100 seeds	New Jersey	Leafy, high-yielding, slower to establish than Cave-in-Rock
Cave-in-Rock	0	166 mg/100 seeds	Illinois	Widely adapted, most widely planted in Ontario
Shawnee	0	166 mg/100 seeds	Selected in Nebraska	A leafy selection from Cave-in-Rock selected for high digestibility, good spring vigour, good drought tolerance
Summer	-8	114 mg/100 seeds	Nebraska	Small-seeded, good lodging resistance, good spring vigour, best-yielding variety with early maturity, not adapted to poorly drained sites and heavy clay soils, excellent drought tolerance
Sunburst	-16	198 mg/100 seeds	South Dakota	Large-seeded, good seedling vigour, excellent winter hardiness, sensitive to rust and lodging, excellent drought tolerance

Switchgrass Seed Quality

Switchgrass seed has an appearance similar to timothy but is about 3-4 times larger. Well cleaned switchgrass seed will have no seed coating and have a weight of 250,000-500,000 seeds per pound depending on the cultivar used. Its seed weight is similar to reed canary grass and it flows well through conventional grass seed boxes. To calibrate a seed drill, the reed canary grass seed chart on the drill is a good analogue for comparison. Switchgrass seed sizes vary considerably so growers should calibrate the drill for each variety used. For successful establishment a seeding rate of 8–10 kg/ha of pure live seed (PLS) is recommended when sowing Cave-in-Rock.

The percentage of pure live seed in a seed lot is determined by multiplying percent purity by percent germination. Use a higher rate of 12 kg PLS/ha in more marginal field conditions or where producers choose to establish the crop without herbicides. Historically, switchgrass has been sold based on its PLS content, as the seed varies greatly in purity and germination. This means buyers only pay for seed that is guaranteed to germinate.

Seed lots with equal amounts of PLS may differ in their volume of bulk seed as seed sizes and weights differ considerably. This must be taken into consideration when calibrating seeding equipment. Newly harvested switchgrass seed can have a high percentage of seed dormancy. Seed that is dormant doesn't immediately germinate after planting. For newly harvested seed, a dormancy rating of 10% or less is excellent. Breeders are working to eliminate the seed dormancy problem, and new seed introductions will minimize this problem in the future.

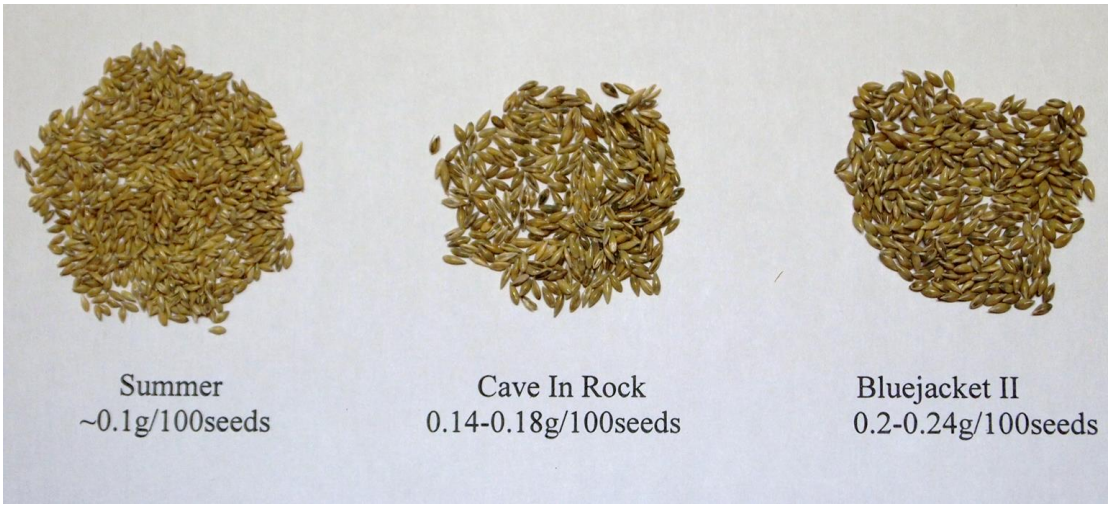

Figure 11. The seed size of upland switchgrass cultivars can vary considerably. Small seeded cultivars such as Summer will have considerable difficulty emerging on heavy clay soils.

Figure 12. The seed quality of switchgrass lots can vary considerably. The seed sample on the left contains small and thin seeds, debris and many hulls are still attached to the seed. The seed on the right has all the seed hulls removed and consists of large plump seeds.

Another seed-quality problem for switchgrass is when seeds have good germination but are just too small. Large seeds emerge more successfully than small seeds, especially on clay soils. High-quality switchgrass seed will be uniformly plump, with the small or thin seeds, seed hulls, and debris removed. Poor switchgrass stands on heavy clay soils are often a result of low-quality seed. Lighter soils generally produce few stand failures. In Ontario, Cave–in-Rock switchgrass seed is generally available through Quality Seeds and directly through seed producers of the Ontario Biomass Producers Cooperative. Less commonly grown switchgrass cultivars can be sourced through Ernst Conservation Seeds from Pennsylvania.

Site Preparation

Site Preparation, Tillage and Planting

Good site preparation is key to establishing a successful switchgrass field. Most of the problems reported by switchgrass growers in Ontario are related to difficulties in establishment. There are four main problems experienced by growers:

1. poor site preparation and soil packing
2. use of poor quality seed
3. planting too deep
4. poor weed control

Figure 13. Getting it right, a good stand of switchgrass emerging in a relatively weed free environment.

Figure 14. and Figure 15. The main weeds to escape are typically annual grasses which tend to emerge a few days earlier than switchgrass. Annual grasses are often wide leafed, prostrate in growth and have multiple stems. Switchgrass generally emerges as a single tiller, is narrow leafed and has a round stem with a purplish tinge at its base.

Soil preparation should typically include one or two secondary tillage passes followed by packing or cultipacking. Packing the soil before and after planting is highly recommended on all soil types. Seeds of switchgrass are small and require planting equipment that can place the seed at a uniform and shallow depth. Seeding can be performed using a regular cereal drill equipped with a forage seed box. In conventionally tilled fields, seeding is best performed with a Brillion seeder at a depth of 0.5–1.0 cm (0.25–0.5 in.).

It is best to seed when soils are relatively warm. Seed will germinate at 10°C, but seedlings grow best when soil temperatures reach 18°C. Seeding usually takes place when the risk of frost has passed, generally between May 10 and June 10, depending on the region. Early seeding is preferable to reduce the risks of hot dry weather after planting. Late seeding should be avoided.

Figure 16. For most conventionally tilled soils, a Brillion seeder generally provides very good results for successful switchgrass establishment. It provides precise metering of the switchgrass seed, a uniform planting depth and a fine, firm seed bed for germination.

Packing the soil before and after planting is highly recommended on all soil types, especially clay soils. Lumpy clay soils will often result in stand failures when preparation and packing are inadequate. Improperly prepared clay soils can suffer from the seedbed drying out. A good rule of thumb for surface soil conditions is that a footprint should be only faintly visible in the soil before seeding. If a small amount of residual seed is not visible on the soil surface after planting, it likely is being placed too deep for heavier clay soils.

On many soils, no-till establishment is an excellent choice. No-till seed drills used for alfalfa can establish switchgrass successfully. Spring soil preparation can increase the emergence of annual weed species. If direct-seeding without a companion crop, prepare the site the fall before planting, then plant with a no-till seed drill the following spring.

Figure 17. In the United States no-till is the preferred establishment method for switchgrass establishment. Very good results are often obtained no-tilling into soybean residue. The field is sprayed with glyphosate before no-till planting to kill early spring emerging weeds such as quackgrass. A packer is used to firm up the seed bed following seeding.

Some farmers in Southern Ontario have had success establishing switchgrass using a companion crop or nurse crop. This concept is discussed below in the "First Year Weed Control" section.

Establishment

Establishment Challenges

The main challenges of establishing switchgrass on Class 1–3 land formerly in field crop production are:

1. annual grass weeds (including giant foxtail, yellow foxtail, barnyard grass, witch grass and crab grass)
2. poor and delayed emergence on heavy clay soils

The main challenges of establishing switchgrass on marginal lands (Class 3–4) formerly in long-term forage crops are:

1. successfully killing existing perennial weeds and forages on the site
2. adequately breaking up clods and developing a suitable seedbed
3. slow crop establishment due to low fertility and/or the low moisture-holding capacity of soils
4. poor and delayed emergence on heavy clay soils
5. coping with the large residual seed bank of germinating perennial weed and forage seeds

Nutrient Application During Establishment

In most cases, nitrogen fertilization is not required in the establishment year, as switchgrass is an excellent nutrient scavenger. Applying nitrogen fertilizer in the seeding year can even prove counterproductive, by stimulating weed growth. Potassium and phosphorus fertilizers are not applied during establishment unless soil levels are low (less than 81 ppm for potassium and less than 10 ppm for phosphorus, according to OMAFRA guidelines for forage crops).

Figure 18. A direct seeded switchgrass stand of Cave-in-Rock switchgrass in the fall of the seeding year on land historically in cash crops. Due to limited annual grass herbicide options, direct seeding often results in a good population of both switchgrass and annual grass weeds. Some Ontario switchgrass growers are now looking to seed under spring wheat as a means to obtain first year income and reduce annual grass weed pressure.

Perennial Weed Control During Establishment

Switchgrass can be fairly slow to form a canopy in the establishment year. It is essential to fully eliminate perennial weeds from the site prior to planting. A comprehensive weed control plan is essential and begins with successfully controlling perennial weeds in the year before establishment.

Perhaps the most challenging situation is converting an old sod field on marginal farmland. These old fields have two main weed problems to deal with: killing and breaking up the existing sod clumps and dealing with the large weed seed bank that may sprout volunteer seedlings of competitive forage grasses such as bromegrass,

orchard grass, red clover and purple vetch. In an old sod conversion, start in the summer before planting and apply a summer and/or early fall application of glyphosate to an actively growing sod. The sod could be mowed several weeks before an application of glyphosate to ensure the application is made during active growth. The newly seeded field will then also require considerable monitoring to address late-season flushes that might arrive in the seeding year.

When switchgrass is planted following an annual field crop, the field can be sprayed with glyphosate in the previous fall or in the spring prior to planting. Perennial weeds such a quackgrass or Canada thistle need to be eliminated on all sites. These weed species can readily invade establishing stands or established stands where weather or soil conditions are not conducive to productive switchgrass growth.

Management During Establishment (Year 1)

Good management during the establishment period is critical, as a switchgrass stand can be kept in production for typically 5 - 8 years. Sections of fields with poor establishment or weed pressure can continue to be unproductive for years, meaning good establishment is critical. In some cases, farmers are content with gaps in fields of poor switchgrass coverage, as these provide habitat for a variety of nesting birds and other wildlife.

Both direct-seeded and nurse crop established switchgrass is typically not cut in the first year, as biomass yield is low and leaving the young material intact helps prevent winter injury. Many farmers have observed that their switchgrass crop does not look very successful in the year of establishment. Common features are slow growth and weed pressure. Growers are encouraged to have patience with thin stands. Switchgrass usually flourishes in the second and subsequent years as long as sufficient seedlings are present at the end of the first year. When good establishment practices have been followed switchgrass will usually flourish in the second and subsequent years. Fields with suitable plant density and canopy cover will often outcompete weeds and establish fairly dense canopies.

Establishment is generally more challenging on marginal (Class 3–4) land that has been in long-term forage production. On Class 1–2 land or lighter-textured Class 3 land with a previous history of field cropping, stand establishment failures are rare.

First-Year Weed Control

Poor weed control is the most frequent cause of switchgrass stand failures. When soil is tilled in the spring, nutrients are made readily available for plant growth. Rapidly growing annual weeds such as mustard, lambs-quarters, pigweed and foxtail thrive on these soluble nutrients.

Key weed management strategies in the establishment year include:

Building up a vigorous plant stand

To obtain the best results, follow planting guidelines and use switchgrass cultivars known to have good seedling vigour. Weed control is greatly aided by a vigorously growing plant stand. There are important differences in the ability of switchgrass cultivars to compete with weeds. Small-seeded lowland ecotypes are generally the slowest to establish. Upland cultivars are now being bred for improved seedling traits for establishment. These new releases have larger seeds, low seed dormancy and emerge rapidly with one erect tiller. These features allow them to capture sunlight and escape from surrounding weed competition quicker and more easily. Sunburst and Cave-in-Rock are larger-seeded cultivars with relatively good seedling vigour.

Planting a nurse crop

In Ontario, many farmers are having good success seeding switchgrass under a nurse crop of spring wheat. With limited registered herbicide options for switchgrass, using a nurse crop simplifies weed management.

A nurse crop can suck up the flush of nutrients from recently tilled soil and help suppress rapidly establishing annual grasses on a nutrient-rich site. If no nurse crop is used, annual grasses often escape and make it very challenging to establish

switchgrass. Stand failures on lighter soils where switchgrass can easily take root are uncommon. On sandy soils with a history of crab grass infestation, it might be best to seed under a nurse crop of spring wheat.

Seeding under spring wheat can also provide income in the first year, before the switchgrass comes into production. Spring wheat appears to be a better choice than oats or barley as a nurse crop. It causes less severe competition to the undersown switchgrass since spring wheat is relatively short in height and early maturing. Harvesting the nurse crop as early as possible can also help eliminate shading of the switchgrass and help encourage late season growth. Some farmers have also had good success with burning off the nurse crop with atrazine to minimize stand failure risks. This strategy enables good early weed suppression and then a quick release of the switchgrass seedlings from the nurse crop competition.

In northern zones (less than 2,400 CHU), nurse crops grown to maturity are not effective as there is insufficient time for switchgrass to develop following wheat harvest. Farmers can use spring wheat or oats as nurse crops and kill them with atrazine in the early boot stage. This has proven to be a successful strategy to control weeds while allowing considerably more time for the switchgrass to grow without nurse crop competition. Some growers could choose to harvest the nurse crop green (at a cutting height above the switchgrass) and use it as a green chop or silage.

Figure 19. Switchgrass underseeded to a spring wheat crop. Spring wheat is the most suitable nurse crop for switchgrass as it is short and matures early.

Figure 20. Switchgrass has established well under a maturing spring wheat crop. The combine cutter bar should be raised to a level which will enable full harvest of the wheat crop without cutting off the growing point of the undersown switchgrass.

Figure 21. After the spring wheat harvest, switchgrass has considerable time to grow in the fall and can often reach a height of approximately 1.5'-2' (45 cm-60cm) by late fall

Note that recommendations in the U.S. are to direct seed switchgrass without the use of a companion or nurse crop. This may be a result of the US Midwest and Northern Great Plains having less favourable moisture conditions than Ontario. Areas to the south and west of Ontario are more vulnerable to drought and high temperature stress which can stunt or kill emerging seedlings.

Using a stale seedbed:

Growers who want to do a late seeding (end of May or early in June) could use a stale seedbed as a weed control technique to reduce annual weed pressure. A "false seedbed" is created several weeks prior to planting to encourage annual weeds to germinate — most annual weeds germinate from the shallow top layer of disturbed soil. The field is then sprayed with a broad spectrum herbicide or is shallow surface–tilled before planting.

Applying herbicides carefully

As discussed above, a good weed control program begins in the previous year to eliminate the presence of perennial weeds. The following information is based on research trials and farm practices in Canada and the U.S. It is the farmer's responsibility to read and comply with the label instructions of each product. Herbicides are mainly used in the establishment year. In poorly established stands or in northern zones, herbicides may also be required occasionally in subsequent years. No herbicides are presently registered for use on switchgrass in Canada. At the time of publication of this document minor use registrations with the Pesticide Management Regulatory Agency are under development for the following herbicides: Aatrex (atrazine), and Buctril M (Bromoxynil + MCPA).

Assess the specific types of weeds present prior to choosing a herbicide program. Research trials in eastern Canada have found that AATREX LIQUID 480 (atrazine, 0.480 kg a.i./L), at a maximum of 1.5 kg a.i./ha/yr, can be applied pre-emergence for upland switchgrass. Some lowland types of switchgrass can be sensitive to atrazine injury. Research trials in eastern Canada have shown that BUCTRIL M (Bromoxynil 0.280 kg a.i./L + MCPA 0.280 kg a.i./L), at a maximum of 0.560 kg a.i./ha/yr, can be used for the control of weeds in established switchgrass.

In Canada, there are limited herbicide options available to effectively kill annual grasses in establishing switchgrass. Switchgrass can be slow growing after planting, creating a major competition problem between switchgrass and problematic annual grass weeds.

Crabgrass is the most problematic weed competing with young switchgrass seedlings. There is no herbicide available in North America that can be used for crabgrass control that does not harm switchgrass seedlings. Annual grass weed control in switchgrass in Ontario remains a challenge if purely herbicide-based options are used. In the U.S., atrazine is used as a pre-emergence treatment and followed by Quinclorac applied to switchgrass once it reaches the 3–4-leaf stage (reached approximately 1 month after planting) at rates of 0.375–0.550 kg a.i./ha.

Figure 22. A research plot where crabgrass has decimated the establishing switchgrass. Crabgrass is the most competitive annual grass affecting switchgrass establishment. Sourcing high quality switchgrass seed, timely seeding and an effective weed control program can reduce the damaging impacts of crabgrass infestations when direct seeding.

Clipping weeds

In the event of a weed invasion in a switchgrass stand, a possible weed control strategy involves clipping the weeds just above the switchgrass canopy. If necessary, clipping can be performed once or twice during the growing season. The main disadvantage of this strategy is the potential to remove the growing point of the switchgrass, which may delay establishment. The growing point of switchgrass is found inside the stem, so clip at a height above the top of the stem.

Combining strategies

Farmers looking to direct-seed switchgrass successfully without herbicides can combine several strategies, including using varieties with good seedling vigour, increasing the seeding rate by 20%, using the stale seedbed technique to flush early weeds and seed in early June and clipping the weeds once or twice at a height above the growing switchgrass seedlings.

Soil Fertility and Nutrient Application

Switchgrass seldom responds to potassium and phosphorus fertilizers. Switchgrass has a very large root system that is well distributed deep into the soil profile for efficient nutrient scavenging. Mature switchgrass stands can have 10-15 tonne/ha of below-ground root mass reaching 3 metres deep into the soil. Rarely does the plant respond to potassium fertilization. The root system is unusually coarse compared to fine rooted cool season grasses. The coarse root system relies on mycorrhizae for the plant to efficiently uptake phosphorus from low P soils. Mycorrhizae are fungal filaments that extend from the root system and help improve nutrient uptake into the plant. Most farmers apply no P or K to switchgrass. One operator has measured increases in soil P over many years, despite no P application. It is suspected that the deep root system is scavenging P and K from below the conventional row crop root zone. A considerable portion of these elements will be recycled back to the soil through the loss of leaves at maturity and the crop overwintering process.

Any solid manure applied to the field should be well decomposed and incorporated. Liquid manure can also be applied as a nutrient source for old hayfields prior to plowing. The main concern with manure application prior to switchgrass planting is that it can increase weed control challenges for establishment if the field is excessively fertile. Switchgrass generally does not need liming in Ontario, as it is very tolerant of acid soils. Because of this, it is a widely used species for coal mine reclamation in the United States.

Stand Evaluation

Switchgrass generally emerges in 5–15 days. The speed of emergence is influenced by soil moisture conditions, soil temperature, soil type and the seed lot. Switchgrass commonly emerges a few days after annual grass weeds. It is common to see grass weeds emerge that are easily confused with emerging switchgrass. Switchgrass seedlings can be difficult to distinguish from grass weeds, especially foxtail. Switchgrass will emerge with a single stem that is round and usually has a reddish tint at its base. Weedy grass seedlings like crabgrass or foxtail are often a lighter green colour, have short wide leaves, and tend to quickly become multi-stemmed after emergence. Switchgrass will generally remain as a single erect stem until it reaches about 20-30 cm in height.

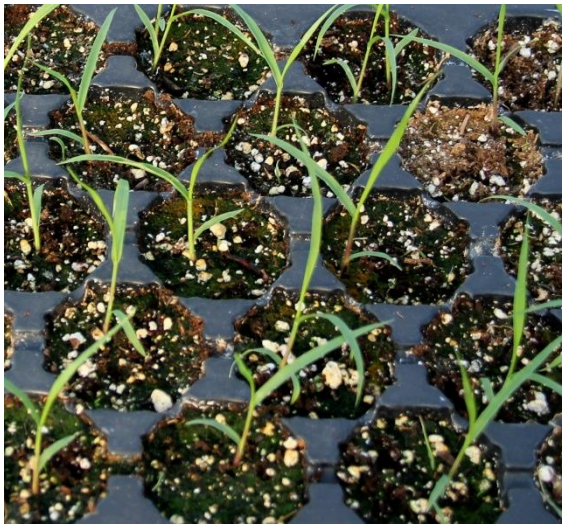

Figure 23. and Figure 24. Seedlings of switchgrass generally emerge about 5-15 days after planting. A relatively long thin single erect leaf will first emerge (left photo). At the three leaf stage (right photo), the noteworthy features which help identify switchgrass seedlings are: 1) switchgrass seedlings which have one single tiller with a round purplish stem base and 2) look for erect plants with relatively long thin leaves.

A reasonable indicator of whether a stand is successfully established is if 10–32 seedlings/m^2 (1–3 seedlings/ft^2) can be found at the end of the establishment year. A more precise assessment can be made using a frequency grid.

Figure 25. A frequency grid placed in the field. Small thin switchgrass seedlings can be observed in the middle two cells. A common lambs quarter seedling can be seen in the bottom left corner.

The system uses a 75cm x 75cm quadrant that contains 25 cells (each cell is 15 cm x 15 cm). The number of cells containing seedlings within the 25-cell grid are counted, not plants per square metre. Applying the grid 4 times gives a count of 100 squares, resulting in an easy percentage measurement (positive switchgrass count in a grid = percentage). Frequency grid values of 50% or higher (20 plants or more/m^2) are considered fully successful stands, frequencies of 25% to less than 50% (10–19 plants/m^2) are considered marginal to adequate stands, while stands with values of less than 25% (10 plants or less/m^2) are counted as unsuccessful or requiring partial reestablishment. Well-established, direct-seeded switchgrass will reach the heading stage by fall. Seedlings that reach a minimum of 30 cm in height will have low risk of winterkill. Growers should make one final assessment of stands in October when annual grass weeds are dead. Switchgrass will remain green until mid-October in the establishing year and is easy to inspect.

Post Establishment Management

Ongoing Weed Management

Once well-established, switchgrass can be highly competitive with weeds, especially on well-drained sites in southern Ontario. Switchgrass has been known to completely eliminate quackgrass from well-drained fields in the southern part of the province. On clay soils and marginal lands, switchgrass will often face ongoing weed problems, especially in the spring of years 2 and 3. Problem weeds will depend on the field history and drainage. Old hay or pasture fields are often the most challenging as they can host a diverse seed bank of quackgrass, red clover, bromegrass, timothy, purple vetch, Canada thistle and dandelions. In most springs, there will be a brief period where a broad spectrum herbicide such as glyphosate can be applied to the field prior to green-up of the switchgrass. This treatment is most risky in the spring of year 2 where no switchgrass should be emerged at the time of a glyphosate application. One-year-old switchgrass plants have limited energy reserves and in early spring can be severely stressed by a hard frost or certain herbicides. U.S. research and grower experience in Ontario has found that, once switchgrass reaches the spring of year 3 and becomes more fully established, applying glyphosate in the spring (on switchgrass up to 4 cm in height) has limited risk.

Nutrient Application

In most cases, the only operation required following harvesting is the application of nitrogen (N) fertilizer. For a spring harvest regime, 60–70 kg of N/ha (50-60 lb/acre) is sufficient to sustain production for a yield target of 8–10 t/ha. A general rule of thumb is to apply 6 kg N/tonne of biomass removed from the field. Over-fertilization with nitrogen usually results in crop lodging, resulting in yield reductions and harvesting difficulties. In mid-to-late May when switchgrass has resumed its growth, fertilization is commonly done when the crop is about 15–25

cm high to minimize N losses if urea is used. Earlier N applications tend to help support grass weed growth, especially annual grass weeds and quackgrass. Switchgrass tends to have its peak N demand in year 3. This is because considerable N is required to fully develop the large root system of the plant.

Most farmers in Ontario mow the crop in late fall, allow it to winter in the fields in a swath and bale early the following spring. Growers in Ontario have found the switchgrass to decompose little over winter when using this system. The grass stays largely in a frozen state and rests on the 10 cm high stubble, keeping the swath separated from contact with the soil. By adopting a spring biomass harvesting regime, phosphorus and potassium fertilizers are usually not required on medium-to-rich soils. Approximately 90%–95% of the potassium in switchgrass is leached back into the soil when the crop is left in the field over-winter. The annual potassium demand is very low when managed as an over-wintered crop as dry switchgrass contains only about 0.1% potassium. A 10 t/ha switchgrass biomass crop will only remove 10 kg/ha of potassium from the field. Producers can sample soil concentrations of P and K periodically to monitor their levels.

Both liquid and solid manure can also be used as a nutrient source. Solid manure or compost would likely best be applied in late May when the crop is actively growing. Switchgrass is a good spring manure application option for farmers with liquid manure as few other fields may be available to farmers at this time. Runoff problems from fields are minimal due to the high soil cover and high infiltration rates (due to the soil having a low bulk density from the switchgrass root structure). Producers should base the rate of manure application on manure N content and target an application rate of approximately 100–150 kg N/ha applied as manure. In the absence of a manure test, a general guideline for a liquid dairy or swine manure rate would be an application of approximately 30,000 L/ha, a relatively modest rate compared to conventional manure application for corn. A general guideline for a solid manure or compost application would be approximately 12 t/ha.

Figure 26. Optimal nitrogen fertility is important for obtaining high biomass yield. Switchgrass on the right was fertilized inadequately.

Pests

Warm-season grasses tend not to be a preferred food of insects. This may be due to the grass's low protein content and low digestibility. Nevertheless, as the acreage of switchgrass expands in Ontario, it is likely that insect problems will occur in the future. To date, no insect damage of economic importance has been reported in switchgrass fields in eastern Canada. The two main pests that are of concern in the U.S. are the switchgrass moth and the switchgrass gall midge. The switchgrass moth has mainly been a problem in the Great Plains and is caused by larva feeding at the base of the plant on tiller buds and internodes. The bigger potential threat for Ontario growers is the switchgrass gall midge, which has been reported in Pennsylvania and New York. It feeds at the base of the switchgrass panicle and causes the head to senesce early. It is readily identified by the presence of dead stalk heads among otherwise dark green panicles.

Diseases

Three important switchgrass diseases have been observed in Ontario: head smut, anthracnose and rust. Of these three, head smut appears to be of greatest concern, especially for older stands on clay soils. As acreage is scaled up in Ontario, growers are proving to be at increasing risk of diseases especially on older stands.

- ***Head Smut***

Switchgrass head smut is caused by the fungus *Tilletia maclaganii.* It is a widespread disease found in most stands at a low level. Head smut can have variable impacts on the yield of biomass stands, with losses tending to worsen as the stand ages. It is seldom reported in young stands. Infection by smut alters the growth of switchgrass by causing stunting of tillers, early flowering (2–3 weeks ahead of normal) and replacement of the seed in the panicle by masses of fungal spores.

Producers should examine infected panicles for head smut if flowering occurs in June (Cave-in-Rock switchgrass typically heads about July 15–25 in southern Ontario). The disease is thought mainly to be seed-borne, though its life cycle is not fully understood. Spores are thought to infect plants through their roots and stem bases. Spores can multiply in great number in the panicle, where they are readily dispersed by wind. Once infected, a switchgrass stand will have the head smut fungus population grow each year until economically important yield losses occur. Head smut is thought to more heavily infest switchgrass on heavier soils than on lighter soils. Spore survival may be higher in the more humid soil environment of clay soils.

Currently there are no economically viable approaches (e.g., fungicides) known that can halt the expansion of head smut in a switchgrass field. The main control/prevention strategies suggested for the disease are to plant more

resistant cultivars and to use cultural practices that limit the spread. Fungicides can be used as seed treatments to help reduce the rate of infection in fields.

Lowland ecotypes to date have been less affected by head smut in the Eastern Great Lakes region. This may be a function of the erect leaf architecture and/or the low prevalence currently of lowland ecotype head smut races in the region. Leafy upland cultivars such as Sunburst and Shawnee appear to be among the more susceptible. Fungicidal seed treatments will help lower the head smut infection rate. However, fungicidal seed treatments are not 100% effective and will only delay onset of the disease. A clean seed-testing program has been suggested as one means to stop seed-borne transmission. Another suggestion is to use seed mixtures of lowland/upland cultivars and/or use more diverse mixtures such as big bluestem-switchgrass. Prairie View Indiana big bluestem is a productive big bluestem cultivar in Ontario and has a similar maturity for use in mixtures with Cave-in-Rock. Finally, keeping stands to shorter rotation cycles will help reduce spore build-up and lower the risk of serious yield losses as stands age.

Figure 27. Head smut should be suspected if the crop is heading several weeks before normal. In most regions of Ontario a healthy Cave-in-Rock stand will not head in June. The head smut is most readily identified in mature seeds. The seeds are often discoloured and mis-shapen, and brownish/black spores fill the cavity of the seed.

- ***Anthracnose***

Anthracnose is the second most important switchgrass disease in the Great Lakes region. It is caused by local fungi in fields and is most present in years of higher rainfall and environments with higher humidity. There appears to be genetic resistance against anthracnose. Plant materials originating in the humid Atlantic coastal region such as Carthage and High Tide are among the most resistant cultivars, while materials originating from the more arid Midwest and Great Plains regions are more susceptible. There is no cultural control for anthracnose, other than planting more resistant cultivars and keeping stands for shorter crop rotations. Improving field drainage will likely discourage anthracnose from developing as it is less of a problem on well-drained soils.

Figure 28. Anthracnose affecting the stem and flag leaf of a switchgrass plant.

- ***Rust***

Certain varieties of switchgrass are also sensitive to airborne rust infection. Rust is blown in from the southern U.S. to cause infections. Germplasm originating from the more humid zones of the eastern U.S. is genetically the most resistant. Cultivars originating from the arid Northern Great Plains are among the most susceptible, including Sunburst, Forestburg and Dakota switchgrass. There is no recommended cultural control other than planting more resistant cultivars and using variety and species mixtures. Rust is more common in summers with higher rainfall.

Figure 29. In Ontario the presence of rust on switchgrass occurs mainly on western originating cultivars such as Summer and Sunburst in summers with extended periods of rainfall.

Long Term Management

Overall, the low labour requirement of the crop and its extended longevity make it an ideal crop for part-time and retiring farmers. Switchgrass stands in Ontario and Quebec have been known to be productive for over 15 years. However the incidence of head smut is now growing and producers should plan to keep stands for 5-8 years. With good planning, switchgrass stand failures should seldom occur. Heaving can occur in switchgrass, but only in the winter immediately following establishment. Winter heaving is mainly a problem in years when alfalfa winter heaving occurs or where seedlings are small heading into winter due to late planting or severe weed competition.

There are significant benefits to soil quality and crop productivity from the inclusion of switchgrass in a field crop rotation, including increased soil organic matter and improved soil structure that will benefit subsequent crops. As switchgrass acreage expands in Ontario, important diseases such as head smut may begin to impact older stands. Growers planting pure switchgrass stands may want to aim to keep the crop for 5–8 years, and then rotate out to another crop. This will help minimize disease risks to switchgrass stands and help growers to capture the positive crop rotation effects on improving field crop yields. The development of nurse crop establishment techniques combined with the use of new high yielding varieties with improved seedling vigor, will likely make these shorter crop rotation cycles with switchgrass more feasible in the future.

Harvest Management & Storage

Harvesting

Most farmers in Ontario choose to cut their switchgrass in late fall and bale material in the spring. As a biomass crop that flowers late in the year, switchgrass production has been found to be optimized when grown as a one-cut-per-year crop in the Great Lakes region. The cutting is performed any time after fall dormancy is well initiated (i.e., at leaf yellowing, usually several weeks after a fall frost). It is commonly cut in the last week of October or early November in areas with heat units of about 2,500 CHU or greater. In cooler zones (<2,500 CHU), it would be cut October 15–30. Late cutting ensures adequate nutrient and carbohydrate translocation to the root reserves to help encourage winter survival.

Figure 30. Mowing switchgrass in the fall with NH10' discbine. Growers should aim to achieve uniform, non-wavy windrows. The discbine speed of travel, cutting height, angle of the cutting bar and width of the swath all must be optimized. The goal should be to make as wide a swath as possible for the planned raking and baling operations. Avoid wavy windrows that have an uneven distribution of the biomass, as this will affect the drying speed and increase the chances of decay in the swath.

The harvest period of switchgrass for biomass production can include late fall, mid-winter (in snow-free conditions) and early spring (anytime between mid-April and late-May). Experience in Ontario has shown that late summer/early autumn cutting can be detrimental to upland switchgrass cultivars and completely kill lowland switchgrass stands.

Cutting green late in the season prevents the crop from translocating nutrients and carbohydrates back to the roots, effectively starving the plant as it heads into winter. Growers looking to cut the crop when it is green in late summer/fall should cut the crop at a 15-20 cm height and only in alternate years to minimize stress on the stand.

When fall-cutting switchgrass, it is best to leave at least a 10 cm stubble to help ensure good winter survival. Shaving stands with a discbine close to the ground risks having delayed regrowth the following spring as well as reduced yields. A 10-cm stubble height helps support carbohydrate translocation from the base of the stems to the plant crowns and roots. Having adequate carbohydrates in the below-ground parts of switchgrass is essential for good winter survival and strong regrowth the following spring. The 10-cm-tall stubble will also help trap snow in the winter and support the swath from having direct contact with soil. This will help facilitate good drying in the spring. To create a simple two-step harvest operation, farmers can lay down uniform swaths in the fall, approximately the width of the bale pick-up.

Many farmers will choose to rake or “flip” the swath in the spring to accelerate in-field drying. A hydraulically driven basket rake or rotary rake is preferable over a ground-driven wheel rake for this operation. Ground-driven wheel rakes tend to pick up more soil, which can reduce the biomass quality of the harvested switchgrass. Raking can also be helpful for improving high-volume baler productivity. Raking can enable several swaths to be brought together for pick-up by a high-volume baler.

In Ontario, producers generally choose a fall cut and spring bale regime for a number of reasons. Switchgrass stems are very slow to dry out in the cool, short autumn days. A fall frost may brown off and quickly dry the leaves of switchgrass. The frost may not penetrate to reach the stems and they may remain green and moist for several more weeks. A high-yielding switchgrass crop can make for a very difficult crop-drying situation. Typically, in the fall, the stems can remain at 30% moisture when the leaves are <15% moisture. If a fall harvest is desired, choose early-maturing varieties to help create an earlier fall dry-down. As well, windrows should be made as wide as possible to promote rapid drying. Macerating technology can also be used to hasten the drying of switchgrass in the autumn period. Another common problem on heavier soils is that field conditions are too wet in the fall to enable transport trucks into the field to remove the baled crop.

Fall harvesting options for switchgrass in Ontario require more research and grower experience. The practice will be more common as higher yielding, early maturing switchgrass varieties become available. As well, some farmers have found success round baling at somewhat higher bale moisture conditions late in the year and storing the bales outdoors. Presently most growers fall cut and spring harvest in most areas of the province where frozen winter conditions prevail.

Figure 31. Wagons loaded with switchgrass bales ready to be transported off the field in the spring.

Delaying baling to the following spring has the advantage of improving winter survival by trapping more snow. Spring harvesting will reduce nutrient removal, resulting in reduced fertilizer requirements. The ash content of switchgrass typically declines from 5% in the fall to 3% in spring, meaning nutrients have leached from the plant and returned to the soil.

By spring, the crop is typically baled at 8%–12% moisture as long days and good drying conditions are present. Some drying can also be expected when bales are placed in covered storage. Commonly, fall-baled switchgrass put into storage at 16%–18% moisture will be at 12%–14% moisture content by the spring.

The main problems that have been identified with overwintering standing switchgrass in fields has been severe lodging and the breakage of the seed heads

and leaves by the late winter winds when the plant is very dry. Typically 20%–30% of the total dry matter can be lost in standing switchgrass fields prior to spring mowing. Delaying cutting the material to the spring can also lead to large harvest losses due to material shattering because of its dry and brittle state at harvest in the spring. Operating a discbine to cut very dry material on stony ground in the spring is also a major fire risk. Several biomass growers in Ontario have experienced fires when spring harvesting with a discbine from sparks coming off of rocks. Farmers should be well prepared for the risk of fire and have fire extinguishers readily available.

Switchgrass fields that are not mowed in the fall are often very difficult to enter in the spring. The heavy biomass mulch causes the field to remain in a cold wet state in the spring for a longer period than normal. Well-drained sandy soils offer the greatest flexibility for farmers in accessing fields under wet weather conditions.

Harvesting Equipment and Systems

Fall-cut and spring-baled switchgrass is an attractive fit for most farm operations because it makes more efficient use of equipment and available labour. The basic equipment requirements for farmers to harvest switchgrass are a mower, rake and baler. There are a few noteworthy differences between harvesting switchgrass and harvesting conventional forage crops. The volume of biomass and the length of the material can make mowing a challenging operation. Most farmers with smaller acreages will use a discbine with a mower conditioner. A larger operation may consider a self-propelled mower-conditioner for the cutting operation.

Figure 32. A self-propelled mower conditioner can be a good choice for heavy crops or for producers requiring a high throughput for larger acreages.

Some farmers will plan to lay down two swaths and consolidate the material into one windrow prior to baling. An alternate strategy to improve field efficiency is to lay down the swath to the width of the baler pick-up and directly pick up the material without any spring raking operations. Where heavy snow loads occur, farmers usually have to rake the windrow in the spring to hasten drying. A heavy switchgrass crop can act as insulation and delay melting of snow and ice under the swath.

Figure 33. Research trials at the farm of Richard Foley in Kinburn, Ontario found that overwintering switchgrass in a snow covered windrow produced higher spring biomass yields than material left standing over winter. If left uncut in the fall, the dry switchgrass becomes brittle and is exposed to the winter elements. Strong winds can result in large standing losses of biomass from breakage (primarily leaves and seed heads) while heavy snows can result in severe lodging.

Figure 34. Switchgrass swath being raked in the spring. Tires, especially those on light farm equipment, can be vulnerable to puncture by the cut stems of switchgrass. Some farmers are filling their small implement tires with silicon to help prevent breakdowns from punctures.

Figure 35. A switchgrass windrow being picked up and baled in the spring. Even in wet springs there is usually sufficient time to bale switchgrass before the emergence of considerable amounts of new growth.

Farmers with large acreages selling to industrial users may want to consider a bulk harvesting strategy. The advantage of this approach is that it avoids baling and bale breaking operations, and minimizes handling costs. This system appears attractive where producers are hauling the product short distances. The material is direct-harvested and blown into a dumper wagon that is used to quickly load transports. The main challenges with this system are the low bulk density of the material and the ability of end users to handle this bulk material. For industrial users, it can be a favourable means to receive material as it requires no bale unloading, de-stringing and bale breaking operations. Transports can simply be tilted and their contents dumped into a large receiving pit.

Figure 36. Large rectangular bales loaded on to a flat-bed truck and ready for transport. When compared to fall harvesting, soil moisture conditions for field entry with large transport vehicles is much better in the spring.

When selling switchgrass off-farm, most farmers are baling with large square bales to facilitate efficient handling and transport. Popular sizes of switchgrass square bales are 3' x 3' x 7.5' and 3' x 4' x 8' (or in metric 0.9m x 0.9m x 2.3m and 0.9m x1.2m x 2.4m). Some large square bales can be loaded directly into enclosed transports with walking floors, which is time efficient and resolves safety concerns with bale loading and unloading operations.

Figure 37. A transport truck with a walking floor can be a fast and safe means to load and unload bales. Many producers will make their square bales 7.5' long to enable transport in enclosed trailers.

Farmers who are using the material on site may choose to round-bale the material. The main advantages of the round bales are:

1. the affordability of the balers
2. the ability to leave the bales in the field prior to field removal
3. the ability to use outdoor storage without cover

A main disadvantage of round bales is that they are not well suited to transport off-site. They do not fit efficiently on transport trucks to enable highway transport. Thus they generally do not provide a cost-effective load weight for hauling in Ontario. For on-farm use, round bales can be quickly and easily picked up by self-propelled bale pick-up wagons designed for round bale handling.

Some farmers are successfully storing switchgrass outdoors for periods of less than 1 year. This is best done by arranging bales in rows with spaces between rows of bales as well as leaving a gap between individual bales in the row. This strategy enables the bale to breathe on all sides and prevents moisture accumulation between bales. Switchgrass is less prone to decomposition in outdoor storage than hay. It has relatively wide leaves and stems and a somewhat waxy surface that enables it to wick water much better than conventional hay mixtures (which can rot relatively quickly if left uncovered). Mature spring harvested switchgrass also has a very low nitrogen content (~.6% N). It is much less prone to decomposition than conventional hay, which is commonly 2%–3% nitrogen. The stored switchgrass bale can also release moisture well, due to its hollow stem structure.

Biomass harvesting and handling is a major cost driver of biomass production. The biomass harvesting system must be well planned for the end use application to provide the lowest cost option for switchgrass growers.

Smaller producers may choose to have their fields custom harvested. This is often a good option, as baling equipment is not in use on other crops in early spring.

Large producers of switchgrass may be able to justify an investment in a high-throughput, one-pass harvesting system.

Figure 38. A large Krone baler with pre-chopper can process large volumes of switchgrass biomass in a day.

Figure 39. Close-up of Krone pre-chopper leaving fine particle dust in the field.

One option being used by straw growers is to chop the material from a windrow, bale it and wrap the bale in plastic in a single one-pass operation. This system has distinct advantages in that the material is pre-chopped and ready to be used by end users. The material is produced in an easily transported shape and is also immediately protected from the elements to ensure a high-quality product. It is a very convenient product for many markets, such as poultry and animal bedding and ruminant-livestock feeding markets. Switchgrass can be a dusty product to chop in a farmyard or barn setting. Fine particulate dust is a health risk to farmers and livestock. Pre-chopping the product in the field seems to be a very logical way to enhance the user-friendliness of switchgrass for diverse market applications. Pre-chopping also increases bale density by about 10% which reduces handling, road transport and storage costs.

Figure 40. A Large rectangular dense bale of pre-chopped switchgrass ready for immediate use by the buyer.

Yield Expectations

Switchgrass typically does not reach full yield potential in the first year. As it is a perennial crop, the plant spends the first year establishing a good root system and preparing to survive the winter. In year 2 (the first production year), yields are generally about 60% of those of fully mature stands on clay soils, and 80% of fully mature stands on sandy soils. On more marginal land or in northern zones, it may take more time for the field to reach full yield potential.

Actual yield will depend on farm location, soil type, crop variety, and crop establishment. Cave-In-Rock varieties in southern Ontario are yielding between 3-5 tonnes per acre. Don Nott and Dan Nott have managed up to 400 acres on good quality land near Clinton Ontario and have averaged 4-5 tonnes per acre. Urs Eggimann has over 120 acres on marginal stony land near Markdale and has averaged 3 tonnes per acre.

Storage Alternatives

The two options to be considered are to store bales indoors or outdoors. Indoor storage ensures the integrity of the product. Bales will typically lose less than 2% dry matter when stored indoors and will dry to approximately 12% moisture. Square bales must be immediately put into storage after baling as the bales do not shed water. Producers can spread a bed of loose switchgrass on the floor or ground under stacked bales to minimize moisture issues for the bottom row of bales.

Buildings can be constructed for storage of both bales and bulk biomass. Costs can be kept modest if vertical space is used efficiently. Some producers stack up to 7 bales high (approximately 6.5 m (21 ft)) to efficiently use floor space.

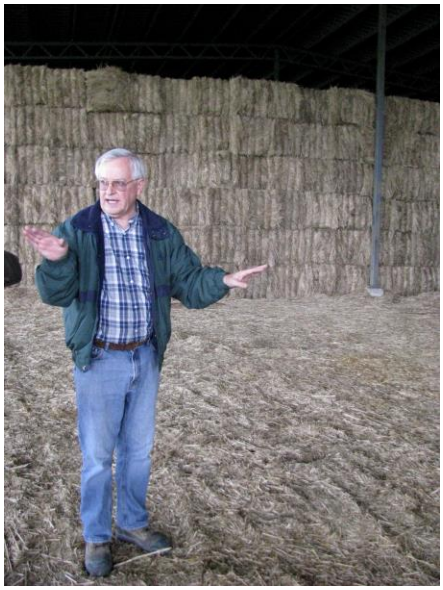

Figure 41. and Figure 42. Don Nott of Clinton Ontario explains his switchgrass metal storage shed facility. Bales are stacked 6 high and switchgrass straw is spread on the floor on top of the crushed gravel.

Some switchgrass producers are successfully storing round bales outdoors. Use of netting wrap reduces dry-matter losses by enabling the material to shed water more efficiently than with the use of a plastic twine. The plastic net wrap compresses the fibre to create a less exposed surface to the elements. Successful outdoor storage is best achieved where excellent drainage is provided to the

bales to prevent capillary water movement into the bales from below. The storage of bales on crushed rock (vs. sod) will reduce dry-matter losses significantly and will better protect bales from decomposing at the bottom. Ontario producers can store round bales successfully outdoors for 6–12-month periods with modest losses (~5%) if they use a net wrap, store the bales on crushed stone and ensure the bales are not touching. Higher losses on the order of 10%–15% may be experienced if they are tied with twine and left on the ground.

Figure 43. One of the lowest cost ways to store switchgrass is outdoors through the use of single round bales covered with a net wrap. The bales are spaced so no two bales are touching. This bale placement technique helps prevent snow buildup over winter and promotes air flow around the bale. Net wraps are made of porous materials that are designed to shed water and allow greater airflow at the surface of the bale. Cover edge net wraps provide the lowest losses as they cover over the edge of the bale by at least 1 to 2 inches. To-edge net wraps cover only to the edge of the bale and allow more possibilities of moisture entry into the bale.

The end-use market plays a key role in deciding the storage system to be used. Some markets, such as the mushroom compost industry, will accept wetter material. Outdoor stacked storage of square bales for brief periods of time may be acceptable for the mushroom compost market. Other markets such as the livestock and poultry bedding markets will require dry material. Tarps can be used on square and round bales but can prove labour intensive to install. Tarp systems work best when used in a sheltered area and for short-term storage periods. Tarps can be used on square and round bales but can prove labour intensive to install and maintain.

Figure 44. Rectangular bales being stored outdoors and covered with a tarp for short-term storage.

To reduce costs, some producers will also simply spread lime on bare ground to create a smooth, hard-packed surface. There are many options for storage of switchgrass material and the most cost-effective option depends on the form of the material to be stored, biomass-quality requirements and the length of time

the material is to be stored. A main advantage of switchgrass is that the material does not spoil readily in storage and is not as prone to spontaneous combustion.

Some producers will choose to sell the material directly in the field if they do not have a storage system available. A new option for farmers looking to store dry switchgrass bales in the field is to use plastic wrap on bales 0.9m x 1.2m x 2.4m (3 ft x 4 ft x 8 ft), stacked 3 bales high. Stinger Corporation offers an in-line bale wrapping system that has the capacity to wrap over 1,000 bales per day.

Converting Old Switchgrass Fields

Eventually, all producers will end up eliminating their switchgrass stands at some point. The most common approach used by Canadian producers to date is to cut and bale the field in late summer/early fall and then moldboard plow. In the U.S., some growers are eliminating stands by no-tilling glyphosate-resistant corn into a re-growing switchgrass crop in the spring. This is best done with no-till corn equipment that provides zone tillage. The stand is then killed by two sequential applications of glyphosate. Switchgrass has very large carbohydrate reserves in its underground rhizomes and roots. These carbohydrate reserves make it highly resilient to surviving stresses such as a severe drought. Farmer experience in Ontario is that a mature switchgrass stand will not be fully killed by a single glyphosate herbicide application. If growing corn after switchgrass, farmers should also be attentive to the nitrogen demand of the slow break down of the switchgrass sod and roots. On conventionally tilled soils, soybeans are a good option as a rotation crop following switchgrass because they fix their own nitrogen. The improved soil quality impacts of long term switchgrass stands generally result in a favourable field crop yield response.

Switchgrass Markets

Switchgrass is now being used in nearly all markets where wheat straw is used. A separate guidebook for livestock uses of biomass grasses is being produced as a companion to this book which discusses the livestock markets for switchgrass in more detail. There are several markets that Ontario farmers are currently selling switchgrass into. The following chart describes the market, and the product characteristics that may be important.

Table 2. Existing Markets & End Uses	**Production Characteristics**
Livestock Bedding: In Ontario the largest market for switchgrass currently is sale to dairy farmers as bedding. Switchgrass has been shown to have a number of advantages over wheat straw. It has more structural strength which provides more comfort to resting and standing cows. It also is not packed down as readily which helps evaporate moisture from the pack. The low nutrient and moisture content of switchgrass also makes it less conducive to causing mastitis infections. The structural strength, absorption properties and low nutrient content also make it a valuable poultry litter. It has also been used with horses, beef cattle, sheep, and even alpacas.	Baled and processed to meet livestock farmer needs including: 1. various fibre lengths: including pre-processed to a finer chop length 2. large or small bales can be used 3. can be de-dusted to produce a premium bedding to minimize dust exposure to horses, cows, poultry as well as farm employees
Livestock Feed: Some dairy farmers have been feeding switchgrass in a mixed ration to dry cows to obtain relatively low potassium levels in the ration. This may have beneficial effects related to reducing risk of milk fever. As well some producers are using low levels of switchgrass (<1 kg/day) in dairy cow total mixed rations to improve rumen function due to inadequate	May include: 1. spring-harvesting to ensure potassium leaching for dry cows 2. late summer or fall harvesting to improve forage quality and intake for milking cows

levels of fibre intake. This application may be most useful for dairy producers that are experiencing depressed milk fat levels.	
Mushroom Compost: Large mushroom facilities in Ontario and Pennsylvania have found switchgrass to be a good substitute to replace winter wheat straw as a substrate for mushroom cultivation. The straw of switchgrass compares favourably to wheat straw as it is fungicide free, high in cellulose content and has good structural strength for helping produce an aerobic compost.	Composters have found spring harvested material favourable to use as the shiny waxy surface of the straw is not as pronounced. Overwintering switchgrass helps speed up the composting processes. Wet bales (up to 35% moisture) of switchgrass can often be sold into the mushroom trade that might have limited use for other markets.
Switchgrass Mulch: Switchgrass has highly desirable properties as a mulch for horticultural applications such as strawberry cultivation or in urban landscaping. Growers in Quebec have demonstrated switchgrass mulch lasts longer and provides better weed control than wheat straw for strawberry cultivation. These traits also make switchgrass suitable for being used as a chopped or pelleted mulch in various ornamental horticultural applications. Switchgrass also holds promise on road construction and building sites as a hydro-mulch and for use in erosion control logs in drainage ditches. Pelletized switchgrass is used around fracking/drilling sites in the US to protect surface waters.	An added benefit of switchgrass over woody biomass in landscape applications is that it has much better impacts on improving soil quality. It also suppresses weeds better than woody biomass mulch and is more effective at retaining soil moisture.
Anaerobic Digestion for Biogas: Switchgrass has been used as an energy crop feedstock for anaerobic digesters in Ontario. As with other energy crop biogas systems, a higher energy price (such as a Feed-In Tariff or Renewable Natural Gas price) is necessary to cover the cost of production of the switchgrass and equipment payback. Ontario analysis shows a roughly equivalent biogas efficiency (cost of crop inputs relative to biogas output) for switchgrass grown on lower grade	Dry bales and ensiled green bales have been digested successfully. Leafy, high digestibility selections of switchgrass such as Shawnee may prove most suitable in Ontario to improve biogas yield and throughput. A cascading value for switchgrass may be achieved by using it first as a livestock

agricultural lands in Ontario compared to high-yield corn silage grown on high quality lands Switchgrass biomass can also be used as a high value livestock bedding and then the resulting manure digested to produce power.	bedding and subsequently as a manure substrate to feed a biogas digester.
Combustion: Switchgrass has been found to be suitable for use in combustion appliances and boilers suitable for higher ash fuels. Many efforts have been undertaken to burn switchgrass as pellets, cubes, briquettes and as a bulk biomass. As a higher value densified fuel it works best as combination fuel with wood residues or crop milling residues such as wheat bran. Recently low energy prices have limited development of this market despite considerable effort by entrepreneurial farmers and businesses to develop this opportunity.	Over-wintering material in the field allows nutrients to leach out, reducing ash and mineral content to improve biomass quality for combustion

Figure 45. Switchgrass (chopped to 4 cm or less) appears to be a promising substitute for wood shavings in broiler and turkey production.

Marketing with the Ontario Biomass Producer's Co-operative

The Ontario Biomass Producers Co-operative (OBPC) is an organization of biomass growers committed to exploring the sustainable production and marketing of biomass. This group is open to all Ontario farm operations, from small to large scale, as well as to associate members who are engaged in the biomass industry. The goal of OBPC is to secure reliable markets for biomass growers, and to collaboratively provide a high-confidence feedstock to biomass buyers. For new growers the OBPC has a lower cost "Start-up Producer Membership" for new biomass producers who do not have any marketable material yet. Full members of the co-op have access to full membership privileges, including the right to participate in market contracts. Contact www.ontariobiomass.com

Figure 46. Dairy farmers are now recognizing that switchgrass is a premium dairy bedding compared to wheat straw. The structural strength of switchgrass appears to provide excellent comfort to resting and standing cows. Compared to wheat straw it is not as readily matted down. It stays drier under the cows as it evaporates water more effectively from the pack. It is also less conducive to growing bacteria and decomposing quickly as it has a low N content and remains drier under the cows.

Economics and Crop Budgeting

The viability of growing switchgrass will depend largely on the cost of production of switchgrass compared to other biomass resources such as wheat straw or miscanthus. Farmers across the various regions of Ontario will experience different yields and input costs which will have a major impact on cost of production. The main cost drivers of switchgrass production are yield, land rental costs and harvest costs. Farmers who can access land that has a low rental value and can grow a moderate to high yielding switchgrass crop generally have the lowest cost of production. Switchgrass is particularly well suited to marginal lands in the warmer zones in the province and to the 2200-2600 CHU areas where farm land has lower opportunity costs due to marginal profitability for corn and soybeans. This is particularly the case when field crop commodity prices are depressed.

A rough breakdown of the per tonne cost of switchgrass production, assuming a ten year stand, is:

- Harvest and Transport: 45%
- Land Rental: 30%
- Fertilization: 15%
- Labour: 5%
- Establishment: 5%

As demand for switchgrass increases in Ontario, farmers are beginning to realize that some of the most profitable areas to cultivate switchgrass are lands that have low profitability in field crop cultivation. An example of two scenarios is found below where farmers in the Ontario Biomass Producers cooperative have made two yield and land rental scenarios over a 7 and 10 year period. In one scenario farmers rent land at $60/acre and produce cumulative yields of 16.5 tonne/acre over 7 year and 27 tonne/acre over 10 years. In the second scenario farmers rent moderately productive land better suited to cash crop production. This land is

assumed to rent for $150/acre/year and cumulatively produces 23.5 and 37 tonne acre over 7 and 10 year rotation cycles respectively.

Table 3. Impacts of Land Costs on Switchgrass Production Costs per Tonne of Cumulative Yield

Year	Marginal Land ($60/acre/yr)	Moderately Productive Cash Crop Land ($150/acre/yr)
	Yield (tonne/acre)	
1	0	0
2	1	2
3	2	4
4	3	4.5
5 and onward	3.5	4.5
7 Year Total Production	16.5	23.5
10 Year Total Production	27	37
Land cost/tonne on a 7 year rotation	$25.45	$44.68
Land cost /tonne on a 10 year rotation	$22.22	$40.54

While the marginal lands likely will have somewhat higher annual costs for establishment and harvesting costs, the differences will likely be modest. However the land cost associated with switchgrass cultivation will be in the order of $18-$20/tonne less with the marginal land. That is to say, on a per-tonne basis, marginal land can produce switchgrass with a lower cost of production than higher quality land. It is clear from the land rent analysis that from an economic standpoint, the introduction of productive switchgrass cultivars that will establish rapidly and be well adapted to marginal lands and the cooler zones of the province will be critical to the expansion of switchgrass as a field crop in Ontario.

Farmers will need to perform their own crop budgets to make their own business case for the crop in their region. The full Switchgrass Enterprise Crop Budget from the Ontario Ministry of Agriculture, Food and Rural Affairs is found below. It is designed to help producers to better understanding the economics of growing the crop.

OMAFRA Switchgrass Enterprise Budget

The OMAFRA Switchgrass Enterprise Budget provides a detailed step by step calculation of switchgrass production costs. A downloadable Excel spreadsheet of this form is available on the OMAFRA website below.

www.omafra.gov.on.ca/english/busdev/bear2000/Budgets/Crops/Forages/switchgrass_static.htm

OMAFRA Switchgrass Cost-Of-Production Estimates

Establishment Costs[1]	**2015 Conventional $ Per Acre**	**2015 No Till $ Per Acre**
Fall		
Fall tillage (disc once)[2][3]	17.00	
Spring		
Seedbed preparation		
Spring tillage cultivating twice (@$13/ac) [3]	26.00	
Packing [3]	7.00	
Seeding		
Seed (10 lbs/ac @ $7.50/lb)[4]	75.00	75.00
Starter fertilizer		
Seeding (drill) [3]	22.00	22.00
Packing [3]	7.00	7.00
Weed control (post-emerge tank mix) [5]		
Spraying [3]	10.00	10.00
Annual grass herbicide		
Adjuvant		
Annual broadleaf herbicide		
Clipping [3]		17.00
Operating interest (operating costs / 2 X 4%)	3.28	2.62
Establishment year land cost [6]		
Establishment failure rate [7]		
Total Establishment Year Costs	**167.28**	**133.62**

[Table continued with annual costs next page.]

OMAFRA Switchgrass Cost-Of-Production Estimates (Table Continued)

Annual Costs – Per Acre	**Per Acre**	**Per Acre**
Establishment costs (over 7 years @ 4%) [9]	27.87	22.26
N fertilizer (60-75 lbs/ac actual N @ 57¢/lb) [10]	38.48	38.48
P & K removal rate fertility costs[12]		
Fertilizer spreading [3]	10.00	10.00
Swathing [3]	20.00	20.00
Turning/raking[3]	8.00	8.00
Baling ($1.23/ft large square) [3] 3x4x8 feet, 950 pounds, 9.3 bales/ac	91.51	91.51
Field removal ($4.75/bale) [13]	44.18	44.18
Storage ($4/bale) [13]	37.20	37.20
Trucking (farm to processing facility) [14]		
Operating interest (operating costs / 2 X 4%)	4.99	4.99
Total Costs Per Acre	**282.22**	**276.61**
Annual Costs – Per Tonne (excluding land)	**$ Per Tonne**	**$ Per Tonne**
Per Acre costs @ 4 tonne/acre (4.4 ton/acre) [11]	70.56	69.15
	Per Acre	Per Acre
Land costs [8]		
Return to Risk & Mgmt [15]		
Total Costs Per Acre		
Annual Costs – Per Tonne	$ Per Tonne	$ Per Tonne
Per Acre costs @ 4 tonne/acre (4.4 ton/acre) [11]		

OMAFRA Switchgrass Cost-Of-Production Estimates (Underseeded with Spring Wheat)

Establishment Costs [1]	**2015 Conventional $ Per Acre**	**2015 No Till $ Per Acre**
Fall		
fall tillage (disc once) [2] [3]	17.00	
Spring		
Seedbed preparation		
Spring tillage cultivating twice (@$13/ac) [3]	26.00	
Packing [3]	7.00	
Seeding		
Switchgrass seed (10 lbs/ac @ $7.50/lb)[4]	75.00	75.00
Spring wheat seed (130lbs/ac @ $ 0.52/lb)	67.60	67.60
Starter fertilizer	73.55	73.55
Seeding (drill) [3]	22.00	22.00
Packing [3]	7.00	7.00
Weed control (post-emerge tank mix) [5]		
Spraying [3]	10.00	10.00
Annual grass herbicide		
Adjuvant		
Annual broadleaf herbicide (Buctril M = 0.4 l/ac x $18.50/l)	7.40	7.40
Clipping [3]		
Harvest and trucking costs (spring wheat grain) [3]	50.00	50.00
Operating interest (operating costs / 2 X 4%)	6.25	5.25
Establishment year land cost [6]		
Establishment failure rate [7]		
Total Establishment Year Costs	**368.80**	**317.80**
Spring wheat revenue (grain) (49 bu x $6.50/bu)	318.50	318.50
Total Establishment Year Costs (less spring wheat revenue)	**50.30**	**0.00**

[Table continued with annual costs next page.]

OMAFRA Switchgrass Cost-Of-Production Estimates (Underseeded with Spring Wheat) (Table Continued)

Annual Costs – Per Acre	**Per Acre**	
Establishment costs (over 7 years @ 4%) [9]	8.38	0.00
N fertilizer (60-75 lbs/ac actual N @ 57¢/lb) [10]	38.48	38.48
P & K removal rate fertility costs[12]		
Fertilizer spreading[3]	10.00	10.00
Swathing [3]	20.00	20.00
Turning/raking [3]	8.00	8.00
Baling ($1.23/ft large square) (3) 3x4x8 feet, 950 pounds, 9.3 bales/ac	91.51	91.51
Field removal ($4.75/bale)	44.18	44.18
Storage ($4/bale)	37.20	37.20
Trucking (farm to processing facility)		
Operating interest (operating costs / 2 X 4%)	4.99	4.99
Total Costs Per Acre (excluding land)	**262.73**	**254.35**
Annual Costs (excluding land) – Per Tonne	**$ Per Tonne**	**$ Per Tonne**
Per Acre costs @ 4 tonne/acre (4.4 ton/acre)[11]	65.68	63.59
	Per acre	Per acre
Land costs [8]		
Return to Risk & Mgmt [15]		
Total Costs Per Acre		
Annual Costs – Per Tonne	$ Per Tonne	$ Per Tonne
Per Acre costs @ 4 tonne/acre (4.4 ton/acre)[11]		

Assumptions for Budget

Note - Assumptions made for the purpose of this budget (costs, yields, etc) are estimates for discussion only, and will change according to research, agronomics and economic conditions. Users should make their own assumptions. As switchgrass is a new commercial crop in Ontario, considerable research and field experience is required in order to answer many of the agronomic and economic questions being asked. Assumptions made in these budget estimates are not to be considered recommendations.

Footnotes to Cost of Production Estimates:

1. Scenarios for both conventional tillage and no-till establishment. No-till establishment may be more practical on some land due to slope and stoniness.

2. This is assuming that the preparation of the field in the season or two before switchgrass seeding gets control of weeds, levels field and otherwise prepares field for switchgrass success.

3. Field operation costs (spraying, plowing, cultivating, seeding, fertilizer spreading, swathing and baling) have been estimated from commercial custom rates and market conditions.

4. Seed costs may change according to supply and demand as a seed industry develops. Seeding rate recommendations may change based on further research.

5. No herbicides are currently registered for use on switchgrass in Ontario. Product registration of herbicides will be required before commercial use. Research is currently being done by the University of Guelph. Recommended products, rates and costs will depend on research results. Minor use submissions for Buctril M and Aatrex herbicides are under

review. Additional herbicides solutions have been prioritized by OMAFRA for future development.

6. Establishment year land cost is used to account for slow establishment that will likely result in no product to sell for the first year. Land costs have the potential to be extremely variable, depending on factors such as location, drainage, slope, and the economics of other land uses, such as other crops and cattle. Land may be available at lower value, but with lower yield potential.

7. Establishment failure rate is used to account for unsuccessful establishment 1 time out of 10. In southern Ontario there is limited risk of a switchgrass stand failure when planted on cropland. On marginal lands and in northern zones switchgrass stand failure rates of up to 20% may be experienced.

8. Land costs have the potential to be extremely variable, depending on factors such as location, drainage, slope, and the economics of other land uses, such as other crops and cattle. Land may be available at lower value, but with lower yield potential.

9. The establishment costs will need to be recovered over the productive life. The costs are amortized at an interest rate of 4% over 7 production years. This will vary widely, depending on agronomic factors such as establishment success and yield, and economic factors such as alternate crop opportunities.

10. Research is required to determine appropriate N rates based on yield response.

11. Yield estimate at 4.0 tonnes/acre are based on a fall cut - spring harvest system. Yields are potentially higher with a fall harvest, but with higher ash content and phosphorus (P) & potassium (K) removal rates. Yields will vary widely depending on agronomics and environmental conditions. An estimate will become more accurate with further field experience in Ontario. Direct seeded switchgrass is typically not cut in the first year and provides no revenue. In Year 2 (the first production year) yields are generally about 60% of those of fully mature stands on clay soils and 80% of fully mature stands on sandy soils. On more marginal farmlands and in northern zones a slower yield ramp up may occur.

12. There is generally no economic response to P and K fertilization of switchgrass when the crop is fall mowed and spring baled. In this budget allocated any costs to P and K fertilization.

13. Removal & storage estimates reflect the cost of moving bales off the field and into storage (building or on skids and under a tarp).

14. Hauling - if the processing plant is pricing based on FOB the plant, trucking costs will need to be included to haul from storage to the plant

15. In order to attract producers, farmers will expect a "Return To Risk & Management" in addition to the COP. This will vary with individual producers, depending on the profitability and risks associated with other crops and investments.

Note: Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement.

Conclusions

Summary of Key Points to Successful Production

- Switchgrass is easiest to establish on well drained soils that have previously been used for annual cropping. If the site is converted from long term perennial forages, make sure the perennial weeds are thoroughly killed.
- First time growers should source high quality Cave-in-Rock seed.
- Conventional tilling and No-till establishment can give equally good results. Pack the fields before and after planting.
- In Southern Ontario farmers have been successful establishing switchgrass under a spring wheat nurse crop to improve grass weed control.
- Do not harvest the switchgrass crop in the fall of the seeding year to ensure good winter survival.
- Switchgrass does not generally require fertilizer in the seeding year. In all subsequent years, switchgrass can be fertilized with 60-70 kg N/ha (50-60/lbs/acre) in late May or early June. Switchgrass will generally not respond economically to lime, phosphorus or potassium fertilization unless soil test indicate levels are very low.
- The crop is cut with a discbine in the fall after the first killing frost. The crop is cut to about a 10cm stubble height and laid into a swath.
- In spring the crop is commonly raked into a windrow to promote drying and baled as soon as drying conditions permit.
- Most farmers producing switchgrass for sale will bale into large square bales for off-farm transport. Farmers growing switchgrass for on-farm use likely will find round baling to be the most economic.
- Square bales can be stored for longer periods in storage sheds or under plastic tarps for shorter periods. Outdoor storage of net-wrapped round bales on a crushed gravel pad is a good option for on-farm use.

Final Word

Switchgrass is a low-input, high-yielding perennial grass capable of impressive yields in southwestern Ontario. Class 1, 2 or 3 land is preferable for obtaining the highest biomass yields. The costs of establishment are high, so field preparation and establishment practices warrant proper attention and care. The high establishment costs are offset by the high biomass yield potential. As well, establishment success is aided greatly by proper seed sourcing.

Switchgrass has a wide harvest window, restricted only by the active growing period of the crop, and flexible harvest and storage options, and results in a biomass feedstock that can be used in an array of end-use applications.

Ever increasing explorations into the potentials for Purpose-Grown Biomass, as well as the constant addition of enterprising individuals into the world of Ontario Biomass, means that there is great space for opportunity, a space that will only grow moving forward into the future.

Figure 47. Group meeting in a well-established field of Switchgrass.

Appendix 1.

Sources of Switchgrass Seed:

Ontario Biomass Producer's Co-operative

www.ontariobiomass.com

(Cave-in-Rock and scaling up improved selections from REAP-Canada)

Ernst Conservation Seeds

www.ernstseed.com

(upland and lowland switchgrass and big bluestem)

Quality Seeds

www.qualityseeds.ca

(Cave-in-Rock)

Appendix 2.

Canadian Sources of Information:

Ontario Biomass Producer's Co-operative

- www.ontariobiomass.com

Ontario Ministry of Agriculture, Food and Rural Affairs Bioproducts Page

- www.omafra.gov.on.ca/english/crops/bioproducts/bioproducts.html

Ontario Federation of Agriculture Biomass Page

- www.ofa.on.ca/issues/overview/biomass

Resource Efficient Agricultural Production (REAP) Canada

- www.reap-canada.com

US Sources of Information:

Native Warm Season Grasses

- www.ernstseed.com/files/documents/native_warm.pdf

Planting and Managing Switchgrass

- www.bladeseeds.com/wp-content/themes/Divi/pdf/Blade-Switchgrass-Mgmt_2ed.pdf

Switchgrass II Conference, Madison, Wisconsin, Sept 2013

- www.dfrc.wisc.edu/switchgrass

Switchgrass III conference, Knoxville, Tennesee, Sept 2015

- www.switchgrassconference.com

10th Eastern Native Grass Symposium, Evansville, Indiana, August 2016

- www.nrcs.usda.gov/wps/portal/nrcs/site/in/home