

# MISCANTHUS Agronomy

# 2016



ONTARIO BIOMASS PRODUCERS CO-OPERATIVE INC.

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# Table of Contents

CHAPTER 1: Miscanthus Basics	1
Introduction	1
Miscanthus as a Biomass crop	1
Environmental Benefits of Miscanthus	5
CHAPTER 2: Site & Material Selection	8
Site Selection	
Variety Selection and Rhizome Quality	9
CHAPTER 3: Site Preparation	
Weed Management	13
Pre-Plant Fertility	13
Tillage	15
CHAPTER 4: Establishment	
Rhizome Planting Density	19
Planting Dates	19
Planting Depth	19
Row Spacing	20
Planting Equipment	20
CHAPTER 5: Post-Establishment Management	24
Weed Management	24
Fertility	27
Pests	29
Stand Renovation	29
CHAPTER 6: Harvest Management	
Harvest Timing	
Harvest Methods and Equipment Options	
CHAPTER 7: Storage & Transport	
Storage	
Transport	40
CONCLUSIONS	

# Table of Figures

Figure 1. Miscanthus as alternate straw for ginseng (D. Smith)	2
Figure 2. Excavated juvenile miscanthus plant ( <i>D. Smith</i> )	3
Figure 3. Second-year harvest-ready stand of miscanthus	3
Figure 4. Mature crop being harvested in late Fall (J. Malecki)	5
Figure 5. Planting rhizomes with no-till planter ( <i>D. Smith</i> )	9
Figure 6. Harvested and prepared rhizomes (D. Smith)	10
Figure 7. Miscanthus plugs grown in greenhouse (D. Smith)	10
Figure 8. Rhizome with unsprouted buds	11
Figure 9. Rhizome already sprouting and leafing	12
Figure 10. Prototype no-till miscanthus planter (D. Smith)	16
Figure 11. Excavated miscanthus rhizome with emerging shoot ( <i>D. Smith</i> )	17
Figure 12. Miscanthus under a soybean nurse crop {field} ( <i>L. Davis</i> )	18
Figure 13. Miscanthus under a soybean nurse crop {close-up} ( <i>L. Davis</i> )	18
Figure 14. Filling prototype planter with rhizomes	20
Figure 15. No-till planter with starter fertilizer tanks	22
Figure 16. W.H. Loxton MP20E miscanthus planter ( <i>H. Loxton</i> )	23
Figure 17. Weed pressure in second-year miscanthus field	26
Figure 18. Inter-row cultivation for weed control( <i>D. Smith</i> )	27
Figure 19. Miscanthus field with <60% establishment	29
Figure 20. Over-wintered miscanthus being cut on frozen ground (D. Smith)	31
Figure 21. Miscanthus being baled in spring after cutting ( <i>D. Smith</i> )	32
Figure 22. Direct-baling a second-year miscanthus stand (D. Smith)	35
Figure 23. Krone BiG Pack 1290 HDP XC with PreChop (J. Malecki)	36
Figure 24. Bale made with Krone BiG Pack HDP XC	37
Figure 25. Switchgrass biomass example of outdoor storage (U. Eggimann)	
Figure 26. Loading square miscanthus bales onto wagon (J. Malecki)	40
Figure 27. Chopped miscanthus ready for use in a poultry barn	43

# **Miscanthus Basics**

#### Introduction

This agronomy basics book provides a summary of research and practical knowledge about growing and harvesting miscanthus. 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 in the Acknowledgments section.

This manual will present the best current knowledge for growing and harvesting miscanthus in Ontario. The guide looks at why miscanthus is considered a promising biomass crop and provides information and guidance on general agronomy; with chapters on the basics of miscanthus as a crop, site and material selection, site preparation, establishment, post-establishment management, harvest management, and transport & storage.

This manual concludes with a summary of key points and considerations for building a successful and well planned miscanthus operation.

#### Miscanthus as a Biomass Crop

Miscanthus, a tall, warm-season, perennial grass native to Asia, is one of the grass species being considered as a purpose-grown biomass crop in Ontario. Current markets being explored for miscanthus biomass in Ontario include animal bedding for poultry, dairy and other livestock production; mulch for ginseng production (Figure 1); provision of heat energy and electricity generation; as a source of industrial sugars like succinic acid; and as a feedstock for sustainable bio-based materials such as bioplastics, bio-based polymers and biocomposite materials.



Figure 1. Miscanthus being used as an alternative to straw for ginseng production in southern Ontario.

Miscanthus reproduces vegetatively through rhizomes. A rhizome is a horizontal, underground stem that serves as a storage organ. The rhizome puts out shoots from buds or from its tip. Figure 2 shows an excavated, juvenile miscanthus plant with good top-growth and horizontal rhizome growth (characteristic of this particular variety). A stand of miscanthus can remain productive for more than 20 years. Figure 3 shows a mature stand ready for harvest.



Figure 2. An excavated, juvenile miscanthus plant showing top growth and rhizome growth.



Figure 3. A second-year stand of miscanthus biomass that can either be harvested now, or stand over winter and be harvested prior to green-up in the spring.

Biomass yield potential is dependent on variety, soil type, growing conditions, and harvest timing. Spring harvesting has been favoured, as it results in better biomass moisture and quality parameters, however, yield is lower compared to fall harvesting. Growers have reported spring-harvested, dry biomass yields in the 17–26 Mg/ha (8–12 t/acre) range. Aiming for 22 Mg/ha (10 t/acre) is a good goal for producers in Ontario.

#### Why Miscanthus is a Promising Biomass Crop

- high yielding ~22 dry Mg/ha (10 dry t/acre)
- low input needs
- no fungicides or insecticides needed at this time
- perennial (20+ years)
- no annual tillage or annual establishment needs
- efficient nutrient use
- large root system
- biomass feedstock suitable to a variety of end-uses in agriculture and the growing Ontario bio-economy
- wide harvest window
- multiple storage options
- environmental benefits
- reduced soil erosion potential relative to annual crops
- beneficial wildlife habitat

#### **Environmental Benefits of Miscanthus**

Growing a long-term perennial grass such as miscanthus has many environmental advantages over the annual cropping systems currently found in much of Ontario. Keeping the same stand year after year means performing fewer tillage operations than would occur with annual crops. This allows the farmer to maintain and even increase soil carbon and, consequently, soil organic matter over time. The intact root and rhizome system and the addition of leaves and other above-ground material (Figure 4) add to the soil each year. Less annual tillage also means less soil carbon is oxidized and emitted to the atmosphere.



Figure 4. Mature miscanthus crop being harvested. The miscanthus biomass that stays in place during the fall and winter protects the soil from wind and water erosion.

With narrow row spacing, the miscanthus plant will grow to fill the spaces inbetween the rows and become effective at preventing soil erosion early in the lifespan of the stand. Having a perennial crop in place ensures that there are not times of the year when soil is bare and prone to wind and water erosion (Figure 4). This helps preserve topsoil in place and reduces the amount of sediment and nutrients moving off-site into surface bodies of water.

A miscanthus crop tends to receive less phosphorus (P) and potassium (K) fertilizer than many annual cropping systems and is an efficient user of nutrients overall. Obtaining high biomass yields with less fertilizer and having fewer opportunities for losses of these nutrients to the atmosphere, groundwater and surface bodies of water is a positive for the ecosystem.

The impact of growing miscanthus on biodiversity and habitat creation in a given area depends on what habitat type the miscanthus field is replacing. The lack of annual cultivation, reduced chemical inputs relative to annual crops and the offseason cold-weather harvest system that can be used in miscanthus would suggest a possible increase in biodiversity and associated ecosystem benefits, but more extensive research is needed in Ontario to fully understand the impact of replacing existing cropping practices with perennial miscanthus stands.

## **Miscanthus Agronomy, Storage and Logistics Snap Shot**

#### **Pre-establishment Planning**

- Site selection (Class 1–3 soils, good drainage)
- Management of problematic weeds
- Soil pH 7.5
- Soil P (>10 ppm) & K levels (>81 ppm)

## **Establishment**

- Tillage (conventional, strip-till and no-till)
- Planting: dates (early is best), depth (~5 cm), final stand density (4,000–5,000 plants/acre), row spacing (0.75–1 m)
- Pre- and post-emergence weed control

## Post-establishment Management

- N fertility (50-60 kg of actual nitrogen per hectare) in year 2 and onwards
- Weed control if necessary

## Harvest Management

- Harvest window: after killing frost in fall, before spring green-up
- Cutting, conditioning, raking, baling

## **Storage**

- Multiple options: indoor dedicated storage buildings, stacking and tarping bales outside, wrapped bales

## **Transport**

- Short haul: tractors and bale wagons
- Long haul: trucks and flatbed trailers

# Site and Material Selection

#### **Site Selection**

Experience in Ontario shows that miscanthus grows best on Class 1, 2 or 3 soils. Miscanthus biomass yields are higher when grown on fertile soils that have good soil moisture-holding capacity, with adequate drainage and good organic matter levels. However, miscanthus has been grown on Class 4–5 soils, though greater risk of poor stand establishment and lower yields in relation to establishment costs may reduce profitability. Fields that are prone to excessive standing water should not be considered for miscanthus. Fields that are high in sand content, particularly in colder regions, should also be used with caution, as there is the possibility of frost penetrating into the rhizome-growing region.

Biomass yield is influenced by a number of factors including accumulated heat units or growing degree days (GDDs) and total sunlight hours, as well as the plant variety selection. Sufficient GDDs are necessary to ensure the plant can initiate growth, accumulate sufficient biomass, develop reproductive tissue and store nutrients to below-ground structures prior to a killing frost. Most of southern Ontario receives adequate GDDs for completion of the growth cycle and the accumulation of biomass. Areas with long, cold winters and low soil temperatures may not be suitable for miscanthus production. Yield and winter survival trials in Kemptville, ON demonstrated that only a few varieties were suitable for production in that area.

The cropping history of the site intended for miscanthus production has important implications for establishment practices. Using land that has a cropping history of Round-up Ready corn or soybeans means that perennial grasses will likely not be a big issue and that weed pressure will tend to be lower than in a field that was previously in pasture (Figure 5). See the section on Tillage in Chapter 3 for further discussion of cropping history.



Figure 5. Miscanthus rhizomes being planted with a no-till planter into a field that previously had corn growing in it.

#### Variety Selection and Rhizome Quality

Miscanthus can be established with rhizomes (Figure 6), plugs (Figure 7) or tissue culture transplants. Using plugs and transplants to establish stands may be more costly, as they require more preparation time in controlled environments and more inputs to produce. Further, the use of plugs and transplants may initially require irrigation to ensure survival, which may not be feasible or economical in most commercial production settings. This document focuses on establishment with rhizomes, which are less costly and more readily available in the province.



Figure 6. Harvested miscanthus rhizomes being prepared for distribution and resale.



Figure 7. Three miscanthus plugs that have been grown in potting soil in the greenhouse.

When purchasing rhizomes, ask the seller if the varieties have been screened for biomass yield potential, good cold tolerance in your growing region and standability in regards to the risk for summer or winter lodging

There is limited experience storing rhizomes successfully for more than a few weeks, though the University of Guelph is currently undertaking research in this area. Generally, rhizomes should be kept in cold storage and harvested and planted within a month. At planting, rhizomes should have two or more unsprouted buds present and not appear to have resumed growth or be dried out. Figure 8 shows a rhizome with three unsprouted buds, ready to be planted. The scales that cover the rhizomes that are usually present have been removed in this case by power-washing, and further roots are present that would likely be trimmed prior to storage and planting. Rhizomes that have shoots already sprouting or leafing out, or that appear to be dried up, should not be planted. Figure 9 shows a rhizome that has already sprouted and budded out during storage. This rhizome has a higher risk of unsuccessful establishment.



Figure 8. Rhizome with unsprouted buds. Some scales are missing because this rhizome was power washed to reveal buds in more detail.



Figure 9. Rhizome that has already sprouted from the buds and even started leafing. This rhizome is past its prime and probably should not be planted.

# Site Preparation

#### Weed Management

Since weed control options are limited, select field sites that have low weed pressure, especially from perennial weeds. Achieving good weed control in the previous crop is imperative. A herbicide burn-down using a non-selective herbicide such as glyphosate in the previous fall can help reduce pressure from winter annuals and biennial weeds.

The "stale seedbed technique" is a weed management practice that involves working the soil well before planting and allowing weeds to emerge for several weeks. A non-selective herbicide such as glyphosate is then applied to kill emerged weeds. Seeding or planting directly into the killed weeds with minimal soil disturbance allows the crop to establish before the next flush of weed emergence. The "stale seedbed technique" before planting miscanthus is recommended when there are few options to control weeds once a crop has been planted and has emerged.

In general, control of grassy weeds has been more difficult in miscanthus because herbicides that are effective at controlling grassy weeds tend to cause unacceptable levels of crop injury and yield loss. Consequently, site preparation has become incredibly important.

#### **Pre-plant Fertility**

Test fields for pH and nutrient levels one year prior to establishment. Apply phosphorus and potassium if soil test levels are less than 81 ppm for potassium, and less than 10 ppm for phosphorus; this recommendation is based on Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) guidelines for forage crops. Soil pH should be in the range of 5.5–7.5. Like other crops that benefit from nutrient availability when soil pH is in the optimum range, miscanthus may benefit from an application of lime if soils test in the acidic range. Apply lime six months before planting to allow for incorporation into the soil and for soil pH adjustment.

Generally, no fertilizer is used in the first year of establishment, as additional nitrogen (N) in the system aids weed growth and spurs competition between weeds and the growing miscanthus plants. Recommendations for sulphur application to miscanthus have not been developed. Sulphur deficiencies have begun to appear in field crops such as wheat in Ontario, so producers should monitor miscanthus for sulphur deficiency.

#### **Planting Setbacks to Prevent Risk of Spreading**

In some contexts, miscanthus may pose an environmental risk in terms of invasiveness. Some ornamental varieties are spread by seed and can propagate in natural areas in an unintended manner. The miscanthus varieties grown in agriculture have sterile seeds, but there could be some risk of spreading through the rhizomes. Rhizome material may spread out from primary fields into adjacent areas. Or, if rhizome material were to break off, it could get transported to another location (for instance, by water) and re-establish a new plot of miscanthus in a natural area.

Most miscanthus varieties commonly grown in Ontario agriculture have rhizomes that spread slowly (<15 cm/year) or that turn upward after growing underground for a short while. Some genotypes, however, have indeterminate rhizomes that spread for long distances (approximately 60 cm/year) and/or that sprout regularly from numerous nodes. For this reason, many resources in the U.S. recommend a setback distance (5–7 m) from ditches, surface bodies of waters and adjacent fields that are not planted to miscanthus. Actively mowing beside field edges may also reduce the risk of spreading.

#### Tillage

Tillage requirements prior to planting will depend on soil type, condition of the field, previous crop or land use, and availability of planting equipment. Where miscanthus follows a soybean or a cereal crop, tillage may only be required if "tough soil conditions" inhibit the planter, either in its ability to place the rhizome at the required 5–10 cm depth or its ability to properly cover the rhizome and prevent it from drying out. In these cases, till to a depth of 15 cm. Where miscanthus follows corn, tillage may also be required to facilitate planter operation as current planter options may not be able to handle high quantities of residue. Where miscanthus is being planted following a long-term pasture or forage, tillage may help control pasture or forage species and perennial weeds.

A variety of tillage implements, including moldboard plow, disk, cultivator, and harrows, can be used, depending on the purpose of tillage. Avoid excessive tillage, as this may reduce the soil moisture required for rhizome regrowth and increase the risk of surface compaction, water runoff and erosion. There is some evidence that miscanthus establishment is most successful with earlier planting dates soon after complete ground thaw. Where deep (15-cm) tillage is required, take care not to work soils that are too wet, particularly on soils with high clay content. Cloddy soils will significantly reduce establishment success compared to soils with stable aggregates and good tilth because of the requirement for good soil contact with the rhizome.

#### Strip Tillage

Strip tillage may fit well with miscanthus establishment. Strip tillage can remove residues and loosen soils only in the strip where the planter will place the rhizomes. Undisturbed areas between rows are less prone to soil erosion during the first few years of the stand. Strip-till across sloped fields so strip-tilled zones cannot act as channels of water flow. In all cases, roll or pack the field following planting to ensure good rhizome-tosoil contact and moisture conservation. Most planters that have rolling or packing capabilities applied over the rows are adequate to ensure contact.

#### No-Till Establishment with a Nurse Crop

In Ontario, experiments with a no-till system for establishing miscanthus are under way. Planting trials are using a no-till planter developed by David Smith (Figure 10, discussed in the Planting Equipment section); these trials include assessing the feasibility of establishing no-till miscanthus with a soybean nurse crop.



Figure 10. No-till miscanthus planter prototype developed in Ontario by David Smith of All Weather Farming.

A no-till planting system would greatly reduce the risk of soil erosion during miscanthus establishment. In the first years of a miscanthus stand, there are large spaces between plants. By year three however, the stand has either filled in completely or a residue cover from dropped miscanthus leaves has formed covering exposed soil. Prior to this, the soil can be vulnerable to erosion.

Reducing existing weed pressure is especially critical when considering no-till plantings. One recommendation is to precede the miscanthus by a herbicide-tolerant crop such as Round-up Ready soybeans, and/or use a winter cover crop that can prevent soil erosion and help reduce weed pressure in subsequent years. Smith uses a rotary cultivator (approximately <1.25 cm) within a year following miscanthus establishment and then plants a soybean crop. He is then able to use herbicides labelled for use in soybeans such as Basagran (bentazon). A first-year miscanthus field established with a soybean nurse crop can be seen in Figures 11, 12 and 13.



Figure 11. Excavated miscanthus rhizomes demonstrating shoot emergence that have been planted in between rows of soybeans.

The combination of a soybean crop and an in-season broadleaf herbicide application results in reduced weed pressure and has the added benefit of producing a marketable soybean crop in the first year to help offset the cost of establishment and lack of a ready to harvest miscanthus crop. Further experimentation with establishing miscanthus in combination with a soybean nurse crop is needed to ascertain whether the system is ideal. Other crops may be used as well, such as corn (under experimentation in the U.S.), and spring cereals, such as spring wheat, oats or barley.



Figure 12. A field trial of establishing miscanthus with a soybean nurse crop. Resulting stand success and first-year miscanthus biomass production are still being assessed.



Figure 13. Close-up of a field trial of establishing miscanthus with a soybean nurse crop. Resulting stand success and first-year miscanthus biomass production are still being assessed.

# Establishment

#### **Rhizome Planting Density**

Rhizome planting density will depend on rhizome quality and equipment availability. The desired final population should be between 10,000–12,500 plants/ha (4,000–5,000 plants/acre). Many researchers and producers of miscanthus rhizomes factor a 25% rhizome mortality rate into their planting plans. This means that 12,000-16,250 individual rhizomes/ha (5,000–6,500 rhizomes/acre) should be used if planting with automated planting equipment. Miscanthus grower John Malecki says that 20,000-25,000 rhizomes/ha (8,000–10,000 rhizomes/acre) is the current standard rate when planting with automated planting equipment in Ontario. Higher planting densities of up to 25,000–30,000 rhizomes/ha (10,000–12,000 rhizomes/acre) are recommended in order to achieve a higher stem density by the second and third year. A higher stem density means that the canopy will close sooner in the growing season and stifle weed growth. Reduced weed pressure and more stems per unit area result in a higher biomass yield within the first few years of establishment.

#### **Planting Dates**

Fields should be established at a time corresponding with the optimal corn planting date for your growing region. Planting too early can be detrimental because it may increase weed competition, particularly from C3 perennial species. Rhizomes only begin to grow when soil temperatures are sufficiently warm and can take up to 3 weeks to emerge. Frequent rains benefit the establishment of this crop tremendously, so planting too late can also have detrimental effects to stand success in drier years.

#### **Planting Depth**

Planting depths range from 5–8 cm, with some growers planting as much as 10 cm deep in dry sandy soils. While it is important to plant deep enough to get sufficient moisture, 10 cm was found to be too deep for some growers and resulted in delayed and uneven emergence.

#### **Row Spacing**

A range of row widths has been used in Ontario. Initially, farmers were using a row spacing of approximately 1 m when using manual planters, due in part to the high cost of rhizomes and the high cost of labour. With the decreased cost of rhizomes, narrower row spacing has been introduced (0.75 m). A narrower row leads to earlier canopy closure in the second year, which will increase yield and reduce weed pressure. A row spacing of 0.75 m also accommodates to the use of nurse crops such as soybeans.

#### **Planting Equipment**

Without specialized equipment, planting can be labour and time intensive. In the past, modified potato planters have been used to plant rhizomes, and vegetable or tobacco planters have been used for transplants or plugs. However, miscanthus rhizome planting machine prototypes have been developed that demonstrate good establishment rates and speed up planting by a considerable margin.



**CHAPTER 4:** ESTABLISHMENT

Figure 14. No-till planter prototype designed by David Smith being filled with rhizomes prior to planting.

David Smith of All Weather Farming in Ontario has developed a no-till miscanthus planter (Figure 10, 14, 15). The unit is based on a modified potato planter and can automatically place individual rhizomes in the soil.

This planter is capable of no-till planting after corn and soybeans, adding nutrients to seed furrow, covering and packing the rhizomes. The planter is a 4-row planter based on 0.75-m row spacing. The hopper capacity depends on rhizome type but holds enough rhizomes to plant approximately 4 ha (10 acres) (Figure 14). At 8 km/hr, it can plant 2-2<sup>1/2</sup> ha (5–6 acres) in an hour, or, 20-25 ha (50–60 acres) per day.

Smith states that bubble coulters (Figure 15) can be used in sandy soils for residue/trash management, and that the cutting-tooth located in front of the planting shoe can be used to loosen soils on heavier ground, such as fields located within the Haldimand clay area. Planter shoes (with adjustable depth) dig the rhizome trench and discs open up the trench where the rhizome is placed. Once the rhizome has been placed in the furrow, a packing wheel and compaction wheel follow to ensure good rhizome to soil contact. The planter is also compatible with starter (liquid) fertilizer application (Figure 15). A squeeze

pump places diluted P, K and a liquid carbon product manufactured by BioFert Manufacturing Inc. directly into the trench with the rhizome. Smith typically applies his starter nutrient mix in a ratio of 3 L fertilizer : 40 L water : 1 L liquid carbon.



Figure 15. No-till planter designed by David Smith, with starter fertilizer tanks being towed behind. Coulters for residue management are on the front of the planter.

Another example of a planter is the W.H. Loxton MP20E miscanthus planter (Figure 16). Specifications for the planter have been provided by Hugh Loxton of W.H. Loxton Ltd. The MP20E is capable of planting four rows at 1-m row spacing, using variable planting rates. The planter is bulk-filled with rhizomes of a known specific density (i.e., numbers of rhizomes per given weight). The operator dials in a weight per acre, and the computer controls the speed of the moving floor in the hopper to plant that weight per acre and therefore a given number of pieces per acre. The distribution along the row is randomized but surprisingly accurate, and the machine will work to within approximately 2%–3% of a chosen weight output. Work rates are typically around 20.2 ha (50 acres) a day, but in larger field sizes with good rhizome supplies and logistics, outputs of over 40.7 ha (100 acres) in a day are possible.



Figure 16. W.H. Loxton MP20E miscanthus planter, manufactured in England. Photo courtesy of Hugh Loxton.

#### **Considerations for Selecting a Planter**

- Size of field
- Number of hectares/day/number of rows per pass/hopper size
- Ability to apply starter fertilizer with rhizome
- Automated/manually fed
- No-till/strip-till compatible
- Depth control
- Trash/residue management
- Variable rates for rhizome release
- GPS compatibility
- Cost of leasing/purchase
- Timing/availability of machine in your area

# Post-Establishment Management

#### Weed Management

#### **Herbicides**

There are no herbicides available in Ontario that are labelled for use in controlling weeds in miscanthus. Research has been conducted by the University of Guelph and OMAFRA to identify potential herbicide solutions for weed control in miscanthus. Table 1 summarizes miscanthus yield loss associated with the application of different herbicides applied at twice their labelled rates (to simulate rates that would occur during a sprayer overlap). A weed-free control was used to make the comparisons among the herbicide treatments. The weed-free plots were weeded by hand and had 0% yield loss.

Table 1: Yield loss of two miscanthus cultivars as affected by herbicide							
active ingreutent, rate and	Rate		% Yield Loss				
Active ingredient (Actv-Ing)	(Active-Ingr. /ha)	Application Timing	Cultivar: 116	Cultivar: Illinois			
weed-free control	not applicable	not applicable	0	0			
dimethenamid-P/saflufenacil	980 g a.i./ha*	preemergence	0	0			
pyrasulfotole/bromoxynil	410 g a.i./ha	postemergence	21	30			
bromoxynil/MCPA	1,120 g a.i./ha	postemergence	23	32			
dimethenamid-P	1,386 g a.i./ha	preemergence	31	70			
dichlorprop-2,4-D	2,034 g a.i./ha	postemergence	34	1			
no weed control (weedy)	not applicable	not applicable	41	15			
chlorimuron + surfactant	18 g a.i./ha	postemergence	52	37			
imazethapyr	150 g a.i./ha	postemergence	75	78			
tralkoxydim + surfactant	400 g a.i./ha	postemergence	81	53			
* The breakdown of each active ingredient rate is 438 g of dimethenamid/ha and 49.6 g of saflufenacil/ha.							

Herbicide treatments were kept weed-free so as to only evaluate the impact of the herbicide on the miscanthus yield. In general, the application of herbicides that only control broadleaf weeds provides less risk of significant crop injury and vield loss to miscanthus than the application of herbicides that control grassy weeds. The exception was when dimethenamid-P/saflufenacil (Trade Name: Integrity) was applied prior to transplanting miscanthus. Crop injury was minimal, and miscanthus yields were equivalent to the weed-free control. The rate of Integrity used in these trials was 584 mL/acre, which contains a 438 g/ha active ingredient rate of dimethenamid-P, the active ingredient that controls grassy weed species in that mixture. When the rate of dimethenamid-P was increased to 1,386 g/ha (3x the rate found in Integrity), crop injury and yield loss were unacceptable. This preliminary work indicates that although low rates of dimethenamid-P appear to offer acceptable crop safety and good early-season grassy weed control, there is a rate response that needs to be investigated further and on a number of different cultivars to establish greater confidence in usage of herbicides containing dimethenamid-P.

The extent of crop injury caused by herbicides depends on the propagule type (seed, plug/transplant, rhizome) and also on variety or genotype. Figure 17 shows a second-year miscanthus field that still has large gaps between plants and significant pressure from annual grasses (row spacing was 1 m).



Figure 17. Second year miscanthus field with weed pressure from annual and perennial grasses. Broadleaf weed on left side of photo has been controlled.

#### **Cultural Weed Control Methods**

Growers who want to mow weeds in the first year must aim to "clip the weeds" without cutting the miscanthus. Miscanthus appears to be sensitive to mechanical injury during the growing season, and location of the growing point may be unclear. If miscanthus has not yet emerged and weed pressure is high, an application of glyphosate can be used to control weeds. Establishing miscanthus with a nurse crop (Figures 11, 12 and 13), as discussed in the planting section is one tool that can aid in weed control.

Inter-row cultivation is used in miscanthus nursery settings and may be applicable in commercial production fields as well (Figure 18).



Figure 18. Inter-row cultivation being performed as a weed control method in a miscanthus nursery.

#### **Fertility**

The rates of phosphorus and potassium fertilization depend on the nutrient removal rates of the harvested biomass crop (see Table 2), biomass yield potential and recommendations for forage and corn crops based on soil testing. Recent research findings in southwestern Ontario indicate that miscanthus yields in the same range as silage corn, and that there is a yield response to applied nitrogen. While miscanthus can produce the same or more biomass than corn, it requires less nitrogen. Nitrogen rates will vary, depending on location, but based on Ontario experience to date, 50–60 kg of actual nitrogen/ha is recommended. Applying nitrogen in excess will not lead to greater yields and can, in fact, cause lodging as well as increased risk of nitrogen loss to the environment.

Manure and composted organic materials are a good fit with miscanthus and should be considered when available and cost-effective. A grower in Ontario (Scott Abercrombie) fertilizes with composted material that tends to be in a 6-2-1 ratio, with the overall aim of 54–71 kg N/ha (60–80 lb/acre) applied.

Table 2. Range of nutrient removal rates of one fall-harvested and two overwintered miscanthus varieties at two sites in Ontario (Engbers 2012) and compared to values in the literature

		Nutrient removal rates*		Literature		
Nutrient	Harvest Timing	Elora	Ridgetown	values**		
Nitrogen	Fall	40–80 kg N/ha	20–25 kg N/ha	20-60 kg N/ha		
	Spring	18–43 kg N/ha	20-25 kg N/ha	-		
	(over-wintered)					
Phosphorus	Fall	6 kg P/ha	4 kg P/ha	3–5 kg P/ha		
	Spring	3 kg P/ha	3 kg P/ha	-		
	(over-wintered)					
Potassium	Fall	30–55 kg K/ha	13 kg K/ha	24–83 kg K/ha		
	Spring	16 kg K/ha	7 kg K/ha	-		
	(over-wintered)					
* Nutrient removal rates are presented as a range that encompasses the outcome of a trial consisting of four nitrogen fertilizer rates (0, 40, 80 and 160 kg N/ha).						

\*\* Kering, et al., 2011. Oklahoma; Propheter and Staggenborg, 2010. Kansas.

Phosphorus and potassium do not need to be applied annually if the miscanthus stand is harvested once a year, after a killing frost and prior to spring green-up. Soil testing and observations of leaf tissue should be ongoing to ensure that P and K levels are in the adequate range. Adequate soil test range is considered as more than 81 ppm for potassium and 10 ppm for phosphorus, based on OMAFRA guidelines for forage crops. With proper harvest management of this perennial crop, highly efficient nutrient use can be achieved, as miscanthus is capable of moving nutrients to the below-ground plant structures during senescence for overwintering.

#### Pests

To date, no pests or diseases have been observed to cause economic harm to miscanthus stands in Ontario. In other regions, fusarium blight, barley yellow dwarf luteovirus (Europe) and miscanthus streak virus (Japan) have been associated with miscanthus, but again have not caused economic losses. Scout miscanthus stands for pests and diseases to identify and address emerging pest problems. Risks of pests and diseases can be reduced by planting multiple varieties, rather than a single variety in a field.

#### **Stand Renovation**

Consider stand renovation activities in fields that have an establishment rate of <60% or within large bare patches, such as in Figure 19.



Figure 19. Miscanthus field with <60% establishment and high weed pressure from poplar saplings.

In some cases, replanting mechanically may be an option. Growers have voiced concerns that stand renovation via hand-planting is time consuming and noneconomical. Furthermore, hand-planted replacements do not seem able to compete as effectively with surrounding miscanthus plants or weeds.

# Harvest Management

#### **Harvest Timing**

Miscanthus is typically not harvested in the establishment year, as the plants are still in a juvenile stage of development, biomass yield is low and harvesting is not economical. In the second year, the miscanthus harvest window commences 2 weeks to a month after a killing frost in the fall and up until the resumption of growth in the spring. Harvest operations can occur on dry soil or when ground is frozen with little or no snow present (Figure 20).

This harvest window is recommended, as it is more likely to result in biomass with a moisture content required for storage and it allows nutrients to be translocated below the ground and/or leach back into the soil. This practice will ensure that rhizomes do not become depleted of key nutrients and that ongoing production of the crop is sustainable. Harvesting before a killing frost could have a negative effect on stand density and biomass yield over the long term.



Figure 20. Overwintered miscanthus being cut in the early spring while the ground is still frozen.

The intended end-use of the miscanthus biomass may govern when and how miscanthus is harvested and what moisture content the biomass is stored at. Harvesting in the late fall results in greater yields and lower field losses than delaying harvest until the following spring, however, the biomass will have a higher moisture content and will need to be stored as a silage using similar practices as would be used for corn silage or haylage. Optimum moisture content for this method is 60%–70% moisture. Given the high moisture content, miscanthus silage may not be economical to transport large distances. Under Ontario conditions, it is unlikely that miscanthus will dry sufficiently to allow for "dry" storage as bales in the fall.

Miscanthus generally has good standability and can be left standing over winter and harvested the following spring. Over-winter lodging, if it occurs, is typically not so severe that a discbine cannot cut and windrow the crop. Miscanthus that is left standing over winter will dry. In the spring, it can be cut and immediately baled once moisture is between 10% and 18% (Figure 21).



Figure 21. Miscanthus biomass being baled in the spring shortly after cutting

Some producers have suggested that miscanthus can be baled at higher moisture contents than forages, due to its low nutrient content, which effectively inhibits microbial activity. Producers may opt to harvest in the spring because they have an intended end-use such as livestock bedding or combustion applications, which require dry biomass material.

#### **Harvest Methods and Equipment Options**

Miscanthus harvesting can be carried out using either a forage harvester or a discbine with crushing or crimping rollers/baler. Both systems are commercially available. The machinery and harvest management system a grower opts to use will depend on equipment availability as well as end-use requirements (bale size, chop size).

"Personally I am still modifying and adapting many different pieces and combinations of equipment. I hope to improve ease, efficiency and speed of harvesting and planting to meet the requirements of various end users."

- Bob Hunter Farms, Ontario miscanthus grower

#### Forage Harvester Method

One method of harvesting miscanthus is with a forage harvester equipped with a rotary head. Self-propelled forage harvesters used for corn silage harvest are commonly used, and custom operators are readily available. Consult the manufacturer about setting up the forage harvester for miscanthus, as settings may differ from corn silage. A pull-type forage harvester could be used, however, most pull-types in Ontario are equipped with a windrow pick-up, so their use would require that the miscanthus is first cut and windrowed using a discbine. The forage harvester method is suitable for producing silage-type material in the fall when moisture content is relatively high. A forage harvester can also be used in the spring when miscanthus is dry (<18%). Dry, chopped miscanthus has low

density, so this system is best suited when the biomass is being used on farm or locally.

#### Disc Mower/Baler Method

An alternative to using a forage harvester is using either a disk mower or a disk mower-conditioner, followed by baling. In the spring, standing miscanthus readily dries to 10%–18% moisture. Baling can occur immediately following cutting by a disc mower (see Figure 22). Given the high biomass yield of miscanthus, take care to avoid plugging the disc mower. Conditioning units can help with the flow of the miscanthus through a mower, but the conditioner unit should be "opened up" to avoid plugging.

Some conditioning methods are not suitable for miscanthus and therefore require either modifications to certain conditioning unit configurations or the disengagement of the conditioner unit(s). Flail conditioning, for instance, is not well-suited to "cane-like" crops or tall grasses. Whereas, metal crimping rolls appear to do well conditioning miscanthus stalks, and better than rubber rolls. Researchers at the University of Illinois replaced the chevron-design, intermeshing molded rubber conditioning rolls with slatted-steel conditioning rolls to increase the degree of conditioning and to make baling of the miscanthus biomass easier. A disc mower conditioner helps facilitate the gathering and baling of miscanthus stalks, which may be too long or too stiff to be gathered and baled efficiently and may possibly cause plugging of the baler. Conditioning can help crimp or break stems and improve flow into the baler.

"...'processed' baling [is] something more than just baling, an added chopping or material conditioning of some kind. This provides a more compact sturdy bale and is beneficial for storage, transport, future processing and applications for end users."

— John Malecki, Ontario miscanthus grower



Figure 22. Front-mounted disc mower direct-baling miscanthus from a second-year stand. Yield obtained was 13.2 t/ha (6 dry tons/acre).

Dry miscanthus biomass can be densified in either large round or large square bales. Large square bales are favoured, as they stack efficiently and more bales can be transported per truckload. The storage options for dry biomass bales are discussed in the Storage section of Chapter 7.

The baler can be operated with or without engaging chopper knives. Some operators may want to engage the knives to achieve a higher bale density or to achieve a chop length desired by the end user. Some biomass applications such as animal bedding, for example, may require a specific chop length. Some producers in Ontario have opted to cut and bale their fields, and then rake up the remaining biomass (primarily leaf material) and bale the raked biomass. This system has two advantages: it increases harvested biomass yield from the field, and it warms the soil faster the following spring by removing the leaf material and remaining biomass, leading to an earlier resumption of growth. Producers in Ontario have stressed that harvest losses can be high if proper care is not taken in selecting the right harvesting equipment and methodology.

A few producers in Ontario use the Krone BiG Pack 1290 HDP XC with PreChop to bale their miscanthus. The PreChop system is an attachment that is installed on the BiG Pack large square baler in front of the pick-up (Figure 23).

PreChop picks up the crop in the windrow and uses rotary knives to feed the crop through two rows of stationary knives, before feeding the biomass into the baler's pick-up.



Figure 23. Close-up of Krone BiG Pack 1290 HDP XC with PreChop attached to tractor.

The unit is able to make high-density bales with dimensions of 0.91 m x 1.2 m x 2.3 m (3 ft x 4 ft x 7.5 ft) that weigh in the range of 450-520 kg (1,000–1,150 lb) each (Figure 24).



Figure 24. A bale made with a Krone BiG Pack 1290 HDP XC with PreChop measuring  $0.91 \text{ m} \times 1.2 \text{ m} \times 2.3 \text{ m}$  (3 ft x 4 ft x 7.5 ft) and weighing 450–520 kg (1,000–1,150 lb).

# Storage & Transport

#### **Storage**

Storage alternatives for the harvested miscanthus are highly dependent on moisture content and the end-use requirements of the biomass. It is important to keep shrinkage/storage losses and reduction in quality to a minimum. The location of storage can either be on the site of production, at a central storage facility (such as one that might be owned by a co-op) or at the site of the end-user. Storage costs will be determined by the age and kind of facility and alternate use.

There are a variety of ways of storing hay-crop silage or "haylage" (e.g., vertical and horizontal silos, silage bunkers, piles, silage bags), however, many of these may be more suited for storing forages that are being used on-farm. Large bale haylage (baleage) is one possible storage option where biomass is stored at moisture contents of 40%-60% (45%-55% is ideal), which may be typical of fallharvested miscanthus biomass. There may be fewer marketing opportunities with large bale haylage, as there are fewer applications for this type of material. Large bales can be wrapped as individual bales with stretch film, or the individual bales can be bagged to exclude moisture. Another option is to use polyethylene flex tubes or employ a multi-bale system for numerous bales, however, this option limits off-farm marketability. Heavier bales may require larger handling equipment, and there are potentially higher storage losses due to the risk of mold development and/or other forms of spoilage. More information on how to prepare and safely store baleage can be found in the OMAFRA Factsheets, Maintaining Quality in Large Bale Silage (Order no.98-069), and Harvesting and Storing Large Bale Haylage (Order no.01-07).

For dry biomass, large square/rectangular bales tend to be favoured as they can be stacked and shipped more efficiently than large round bales. Miscanthus used as a seedless mulch or straw in ginseng production is prepared in round bales. Round bales of miscanthus for ginseng application could potentially be stored outside for at least one year. Unlike round bales, square bales do not shed water and have to be covered during storage. The major types of storage options for dry bales include:

- Indoor storage
- Outdoor storage on a dry concrete pad (or a thick layer of biomass to prevent moisture wicking) with tarps to repel snow and rain penetration
- In wrapped bales stored outside, either in single rows or rows with multiple levels

Figure 25 shows an example of biomass bales being stored outdoors under a tarp.



Figure 25. Biomass bales being stored outdoors in a formation of seven bales (2 + 2 + 2 + 1). The three major stacks were covered with new hay tarps of 14.6 m x 8.5 m (48 ft x 28 ft).

The dry hay storage moisture guidelines for large square bales and large round bales with a hard core suggest a moisture content of 12%–15%. Large round bales with a soft core can be stored at 13%–16% moisture. (See OMAFRA Publication 811, *Agronomy Guide for Field Crops — Forages — Harvest and Storage*). There is some evidence that miscanthus can be baled at higher moistures than usual for forages, due to low nutrient content.

#### Transport

Transportation costs are significant to the overall profitability of producing miscanthus. The equipment used will vary, based on the distance to the storage facility and/or end-use destination. As with similar crops, tractors and bale wagons can be the primary mode of transportation between the field and localized storage locations (Figure 26). Moving the material from the field or on-farm storage to further destinations will require trucks with flatbed trailers capable of bearing heavy loads.



Figure 26. Miscanthus square bales being loaded onto a wagon for transport off the field.

40

# Conclusions

#### **Summary of Key Points to Successful Production**

- prepare the field: low weed pressure, adequate P and K levels
- plant high-quality, properly stored rhizomes
- plant as early as possible after ground thaw
- start applying nitrogen in year 2, onwards, at a rate that boosts yield but does not lead to lodging
- do not harvest biomass in the first year
- harvest miscanthus in year 2, onwards, after a killing frost and prior to spring green-up
- condition biomass prior to, or as part of the baling operation, to create a compact, more sturdy bale
- rake and re-bale fields after first harvest pass to maximize collection of harvested biomass

#### 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

#### **Final Word**

Miscanthus is a low-input, high-yielding perennial grass capable of good yields in southwestern Ontario. Class 1, 2 or 3 land is preferable for obtaining good biomass yields. There are risks of overwintering death in the first year of establishment in some growing regions and/or when rhizomes of poor quality are used.

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. In addition, the cost of rhizomes is expected to decrease over time.

Miscanthus has a wide harvest window and flexible harvest and storage options, and results in a biomass feedstock that can be used in an array of end-use applications. The ongoing development of a no-till planting system that accommodates a soybean nurse crop is an exciting prospect for Ontario producers.

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 27. Chopped Miscanthus ready for use as Bedding in a Poultry Barn.