Field-Scale Agricultural Biomass Research and Development Project Final Report

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November 2013

The authors would like to express their appreciation to the many producers who participated in this program. Without their valuable feedback much of this would not have been possible.

We would also like to extend our appreciation to the following people for their valuable inputs and feedback:

Producer Organizations:
Ontario Biomass Producers Co-op
Ontario Federation of Agriculture

Producers/Individuals:

Don Nott, Nott Farms
Charlie Lalonde (CJ Agren Consulting)
Scott Banks (OMAF and MRA)
Ian McDonald (OMAF and MRA)
Mike Cowbrough (OMAF and MRA)

Investment in this project has been provided by Agriculture and Agri-Food Canada through the Canadian Agricultural Adaptation Program (CAAP). In Ontario, this program is delivered by the Agricultural Adaptation Council.

AAC agricultural adaptation council

Agriculture and Agri-Food Canada   Agriculture et Agroalimentaire Canada

Executive Summary

This report summarizes the findings of the field-scale agricultural biomass research and development project undertaken by Ontario Soil and Crop Improvement Association (OSCIA). The project was as a component of a larger study of developing an agricultural biomass value chain sector in Ontario lead by the Ontario Federation of Agriculture (OFA). Support was provided for Ontario farmers to obtain on-farm pilot scale field-plot experience with purpose grown biomass crops over four growing seasons (2010-2013). By encouraging this adaptive research, it would allow farmers, who are very adept at developing solutions to their individual problems and circumstances, to develop site-specific solutions to agronomic and productive capacity challenges with purpose-grown biomass crops.

Twenty eight producer co-operators were selected based on submissions of Applications of Interest and reviewed by a selection committee comprised of OFA, OSCIA, OMAF and MRA extension staff and University of Guelph researchers. Eleven co-operators had biomass crops already established while 17 new planting projects were planted in the spring of 2012. Three purpose grown biomass crops were targeted as the focus of the study, these included; Miscanthus, switchgrass and tallgrass prairie. These species were selected for their high yield potential, high energy and nutrient efficiency and wide adaptation of C4 perennial grass species relative to dedicated annual species in Ontario. Prior to this project, field production experience in Ontario with Miscanthus, switchgrass and tallgrass prairie has been limited to a few early adopters and research trials. Information on producer experiences with all aspects of biomass grass production were obtained through annual co-operator surveys, co-operator reported yields and harvest moistures and field data collected by OSCIA staff.

The 28 producer co-operators experiences were broken down into 56 plots to capture different comparisons of species, ecovars, year of establishment, and planting method. Plots represented a wide range of soil types, land classifications and a wide geographic dispersion. Field selection and preparation, variety selection, planting methods, planting timing and establishment, weed management practices and corrective measures for poor stand establishment used by co-operators are outlined in detail in this report. Field selection/preparation, planting timing and

weed management were the key factors impacting crop establishment success and yield potential.

Field preparation for successful crop establishment was not crop, location or soil specific but specific to the cropping system being displaced. Soybeans are the preferred crop to precede establishment of biomass grasses as they are associated with little residue, the opportunity to use no tillage which enables a firm seedbed preferred by switchgrass and native tallgrass prairie, and are associated with primarily an annual weed complex that is less competitive and easier to control subsequent years. Conversely establishment of biomass grasses into hay, pasture or alfalfa can be difficult due to the need for tillage to control the previous crop, and the presence of a more competitive, more difficult to control perennial weed complex.

Planting timing also strongly influenced the establishment success and weed pressure of the biomass plots in this program. April to May planting of all grasses resulted in increased establishment success compared to later plantings. Early planting has lower weed pressure and competition for sunlight, soil moisture is higher and there is a longer growing period. Delayed planting date and increased winterkill were the most common cause of stand failure reported by co-operators in all of the biomass crops.

In addition to reducing the potential weed pressure by early planting into a field with minimal tillage and a less competitive annual weed complex. Weed management practices were investigated by co-operators to encourage successful establishment. Mowing of weeds in the spring and early summer above the establishing grass crop seedlings was most commonly used in the initial establishment phase. Beyond the first year of planting, herbicide use was most common method of weed management. There are currently no herbicides registered for use on Miscanthus, switchgrass and tallgrass prairie. Co-operators were required to base herbicide decisions on recommendations from other jurisdictions and from the limited herbicide evaluation studies conducted to date in Ontario. Co-operators used a wide range of herbicides. The herbicides used are currently registered for use on other crop species grown in Ontario and application rates and use patterns for Miscanthus, switchgrass and tallgrass prairie were similar to that used in crops currently on the respective herbicide labels.

Co-operator experiences with crop fertility requirements, insect and disease pressure and lodging were all documented by the study but were not considered major influencing factors in crop establishment. However as stands mature fertility requirements, monitoring insect and disease pressure and lodging will likely become of greater concern to producers for maximizing yield potential. Producers based fertility management decisions on recommendations from other Ontario biomass grass producers, production guides, research trials by the University of Guelph and OMAF and MRA and recommendations from the seed or rootstock suppliers. Complexities observed in general recommendations of field crop species, such as corn, may need to be developed for switchgrass, Miscanthus and tallgrass prairie. Further research will be required to develop crop specific fertilization recommendations of established crops as the biomass industry develops in different regions of Ontario.

The lack of observed insect and disease pressure by co-operators in this project is consistent with the observation by producers and researchers from other regions that there are currently few insect and disease pests of economic concern to Miscanthus, switchgrass and tall grass prairie. However, as acreage of these crops increase in Ontario monitoring of insect and diseases is required.

Lodging of perennial grass biomass stands is a concern because lodging can negatively impact yield, biomass quality and harvest efficiency. The extent of the impact is presumably related to the degree of lodging and recovery from lodging that occurs. Based on observations in the present project, Miscanthus, switchgrass and tallgrass prairie all have the potential to lodge. Co-operators did not report lodging having affected harvestable yields in any of the grasses from 2010 to 2012. However, as maturing stands near closer to maximum yield potential and fertility requirements continue to be investigated the potential for lodging and its effects on harvestable yield will need to be monitored.

Harvesting of biomass crops was done with existing field equipment in the spring. Switchgrass and tallgrass prairie plots were mowed in the fall and baled in the spring while Miscanthus was left standing overwinter and baled in the spring. Baling using a large square baler in the spring is optimal for low harvest moistures (6-12%) and maximum bale weight for transport. When baled at the low moisture contents reported no problems with storage either indoors or outdoors were reported. The low moisture contents may also reduce drying costs and transportation costs to the end user.

Yields reported by co-operators were highly variable with age of establishment, location and within crop species. Established (≥ 3 years) Miscanthus plots achieved an average yield of 18 t ha^{-1}, while established switchgrass plots achieved an average yield of 3.6 t ha^{-1}. Miscanthus yields observed by co-operators are in line with literature estimates for Ontario (Kludze et al. 2011). However co-operator reported switchgrass yields are much lower than literature estimates for Ontario (Samson, 2007). Switchgrass plots in this program may have represented more northern locations with shorter growing seasons and marginal soils than addressed in research programs in Ontario to date. Overall, co-operators commented that stands were slower to establish than expected and time to achieve reasonable yields took longer than anticipated. Further research is required to determine the time required to reach full yield potential of the different grasses, and switchgrass in particular, across Ontario.

In conclusion, Ontario biomass producers have been able to develop site-specific solutions to agronomic and productive capacity challenges with Miscanthus, switchgrass and tallgrass prairie crop production. However other more specific questions related to variety selection, control of perennial grass weed pressure, fertility requirements and the time required for achieving full yield potential in a range of soil and climactic conditions still remain. The lack of stable biomass markets and end-uses has delayed the development of specific agronomic recommendations. As more stable and profitable markets evolve agronomic and productive capacity challenges will continue to be developed by Ontario farmers.

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1. Introduction

1.1. Agricultural Biomass in Ontario

The Ontario agricultural industry has the potential to supply agricultural biomass to a range of emerging green economy markets, from heat and power to bioplastics and biochemicals. Agricultural biomass opportunities in Ontario have evolved as a means for different industry sectors (energy, automotive, chemicals, etc.) to reduce fossil fuel consumption and dependence. Initial market analyses focused on the feasibility of an agricultural biomass industry for combustion energy in Ontario. Agricultural biomass was identified as a potential replacement for coal in two Southern Ontario power stations during the initial stages of this project. As a result of reduced power demands across the province, markets for agricultural biomass for large scale heat and power generation have not been required. Opportunities for an agricultural biomass industry for heat generation on small and medium scales, as a filler in plastics and non-structural building materials and conversion to industrial chemicals, to name a few, represent large opportunities for the agricultural industry in Ontario.

In addition to market development, biomass feedstock selection has been investigated in Ontario. Agricultural biomass feedstocks are defined as either crop residues (such as straws and corn stover) or purpose-grown biomass crops (such as Miscanthus, switchgrass and tallgrass prairie). The availability and sustainability of crop residue removal has been addressed in two Ontario studies (Kludze et al., 2010 and Oo and Lalonde, 2012). While both reports conclude that some residue removal is feasible, the quantity that can be removed sustainably is site specific and the long term effects of residue removal on soil quality are unknown. The ability to supply large quantities of biomass from crop residues would require a change in current agricultural production systems, specifically in crop rotations, tillage practices and utilization of cover crops. For these reasons, biomass may be supplied more sustainably from purpose-grown biomass crops without significant effects on the current production and supply systems of existing annual field crops (Kludze et al., 2010). Purpose-grown biomass crops have the potential to produce high yields of biomass consistently for a long period of time and have low nutrient requirements.

1.2. Purpose-grown biomass crops

Experience with purpose-grown biomass crops is limited in Ontario. High yield potential, high energy and nutrient efficiency and a wide adaptation of C4 perennial grass species relative to dedicated annual species has been the motivation for research efforts and some limited production of the grasses by Ontario producers. The species of particular interest in Ontario are Miscanthus (*Miscanthus* spp.) and switchgrass (*Panicum virgatum* L.), and to a lesser extent tall-grass prairies species. A brief literature review of the three cropping species is provided in Appendix A.

1.3. Overview of Ontario experience with Miscanthus

Miscanthus is a genus of C4 perennial grass species native to Eastern Asia. Within the genus, two species and one interspecific hybrid are of particular interest for bioenergy production, *M. sinensis, M. sacchariflorus* and *M.* x *giganteus.* The Miscanthus species *M.* x *giganteus* has been evaluated most extensively in North America as this hybrid is sterile, exhibits added yield potential as a result of hybrid vigour and is thought to have low potential for invasiveness (Beale and Long, 1997). Miscanthus production in Ontario, both at the research and producer level, was initially adapted from experience in Europe where it was considered to be the energy crop with the greatest potential for biomass production. Some of the first producer experiences in Ontario with Miscanthus production in Ontario (New Energy Farms, Leamington; Gildale Farms, St. Mary's) evaluated several varieties in the early 2000's and selected several varieties with the potential to overwinter in Ontario conditions and produce yields of ~ 10 tonnes ac^{-1}. Research trials initiated by the University of Guelph and OMAF and MRA, also demonstrated high yield potential and adaptation. The present project represents an opportunity for a broader range of Ontario farmers to produce Miscanthus on a field scale under a range of soil and climactic conditions and an opportunity to glean information from their experiences.

1.4. Overview of Ontario experience with switchgrass

Switchgrass is a C4 perennial grass species native to North American tallgrass prairies. Monoculture production of switchgrass for biomass potential in Ontario has been adapted from experience in United States and Quebec (Lewandowski et al., 2003; Samson, 2007). Early agronomic recommendations for Ontario were identified by Samson (2007). Cave-in-Rock and other varieties adapted to the Eastern United States were recommended to be best suited to Ontario conditions with potential yields of 3.2 to 4.9 tonnes ac^{-1}. Like Miscanthus there were a limited number of producers (Nott Farms, Clinton; Willowlee Sod Farms, Ameliasburgh) with switchgrass production experiences before the late 2000's. Also like Miscanthus, various research plots have been established by the University of Guelph and OMAFRA. Producer and researcher experience again demonstrate the potential for switchgrass to be grown in Ontario. While yield potential for switchgrass (~ 3-4.5 t/ac) is lower than Miscanthus, costs of production may be offsetting. The present project represents an opportunity for a broader range of Ontario farmers to produce Miscanthus on a field scale under a range of soil and climactic conditions and an opportunity to glean information from their experiences.

1.5. Overview of Ontario experience with tallgrass prairie

Tallgrass prairie refers to a mixed polyculture of perennial grass and forbs species that are native to Ontario. Tallgrass prairie is a climax vegetation and as such may have potential ecological benefits as it allows for establishment of different grasses within fields with varying soil conditions and drainage. Given its potential ecological benefit it was included in the present project Tallgrass prairie has been planted by several ecological restoration associations across Ontario (Tallgrass Ontario, Rural Lambton Stewardship Network, Alternative Land Use Services Norfolk, etc.) but the exact acreage is unknown. Prior to the present project, no tall grass prairie had been grown for biomass and consequently, feasibility of commercial production and harvest, as well as yield potential has not been determined.

1.6.Project Introduction and Objectives

In 2010, the Ontario Federation of Agriculture (OFA) began a comprehensive research initiative entitled "A Transformative Project to Generate Energy for Ontario by Developing an Innovative Agricultural Biomass Value Chain Sector." The objective of this initiative was to determine if growing biomass crops are a viable commercial crop option for Ontario farmers and to understand how producers can maximize their returns from this emerging opportunity. The Field-scale Agricultural Biomass Research and Development Project described in this report is a sub-project related to this overall objective. While, the project objectives addressed by OFA and the other project co-operators focused mainly on production segments of the value chain, the present project led by Ontario Soil and Crop Improvement Association (OSCIA), which is sub-project of the OFA project, was devoted solely to field pilot plots and research.

The objective of this sub-project was to support Ontario farmers to obtain on-farm pilot scale field-plot experience with purpose-grown biomass crops. The project aimed to assist farmers in identifying success factors for establishment, production and market development of purpose-grown biomass over 4 growing seasons (2010-2013). By encouraging this adaptive research, it would allow farmers, who are very adept at developing solutions to their individual problems and circumstances, to develop site-specific solutions to agronomic and productive capacity challenges with purpose-grown biomass crops.

2. Project Methodologies

2.1.Selection of Producer Co-operators

To participate in the project, producers completed an Application of Interest form, developed by OSCIA, in one of two intake rounds in June and October of 2010. To assist potential collaborators in completing an Application if Interest form, an Application Guide was developed by OSCIA, this provided explanations for the purpose of the biomass on-farm field plots and project expectations of the farmers. The Application of Interest collected information from each of the potential co-operators on:

1. General farm information such as location, size, commodities, soil classification, drainage, etc.
2. Experience in working with research and extension for on-farm applied research;
3. Accessibility of proposed sites for field days and on-farm demonstration and willingness to host such events;
4. In-kind contribution that demonstrate personal commitment to the success of the project;
5. Proposed planting, agronomic management, harvesting, and storage of the biomass product;
6. Proposed intended market and proximity for modest transportation costs;

The Application of Interest and the Application Guide, along with supporting material and contact information, were posted on a devoted webpage linked to the OSCIA website. To further assist producers interested in participating in the program, information sessions were organized in Norfolk county (Simcoe), Kent county (Ridgetown), and Oxford county (Woodstock) in June 2010 and through an online seminar in October 2010. Notices for these meetings were placed in The Grower, on the OSCIA and OFA websites, OSCIA provincial newsletter, distributed through the OSCIA Outreach Coordinator via Twitter and blog and through Regional Communication Coordinators via Twitter, regional blogs and newsletters. Over 7,000 producers in Ontario received these notices. At the information sessions held in June, 62 producers attended and in October, 31 producers were registered and the video was made available online for the duration of the intake period. Fifteen Applications of Interest were received in the first intake and nineteen in the second.

A Selection Committee, comprised of representatives from OFA, OSCIA, OMAF and MRA extension staff and University of Guelph researchers reviewed the applications. Applications of Interest were evaluated anonymously and scored based on criteria outlined in the Application Guide. Applications of Interest were also reviewed to ensure geographical dispersion across Ontario so that a range of climactic conditions, soil types and land capability classes, as well as market opportunities would be incorporated into the project. In addition, Applications of Interest were evaluated based on costs requested for compensation and the level of contribution to the project as in-kind. Finally, the project only considered purpose-grown, perennial, herbaceous crops. Applications of Interest based on annual herbaceous species or woody perennial species were excluded.

OSCIA did not receive final project approval till late in the 2010 growing season, as a result, the first Applications of Interests approved were for farmers who already had a dedicated biomass crop established. Nine collaborators were approved in the first round. The second round of Applications of Interest was targeted at new producers who did not have previous experience directly with the biomass crops. Seventeen applications were approved in the second round. Fifteen of the approvals in this round were for biomass plots that were established in the spring of 2011. Two of the approvals were to support established dedicated biomass crops. Finally, OSCIA accepted two additional Applications of Interest in the fall of 2011 and approved two collaborators with established biomass plots.

Overall, the steering committee selected 28 producer collaborators (Figure 1). In addition to the plots established by producer collaborators, one plot was established at Canada's Outdoor Farm Show (COFS) site in Woodstock, ON. This plot was established to encourage knowledge translation and transfer at the farm show. It also provided some data collection opportunities. The plot was a joint effort by OSCIA and COFS staff, and two producers nearby already in the program. The 29 projects represent 725.1 ac of biomass grass production.

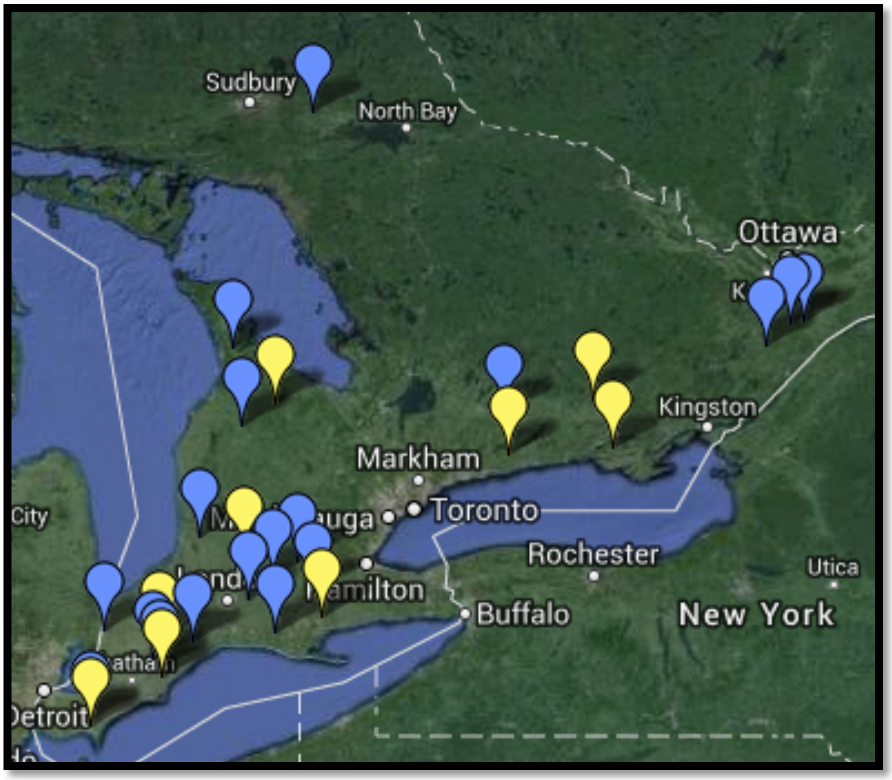

Figure 1.1- Producer collaborator locations in Ontario. Yellow and blue markers represent projects accepted in first and second round of applications respectively. Project in Rainy River District not shown on map.

Successful applicants were required to sign an Agreement that outlined terms/conditions they must meet to receive compensation for their expenditures. Ultimately they were required to establish biomass plots as per there proposed management outlined in their respective Applications of Interest. OSCIA did not dictate to producer collaborators any management approaches but rather gave them complete independence. If requested, assistance was provided by OSCIA to refer applicants to existing literature on biomass production. In some cases applicants were encouraged to add into the agreement comparisons of biomass management or biomass species. For example, applicants with established dedicated biomass crops were encouraged to incorporate comparisons of weed control methods or fertility rates, while applicants with no established dedicated biomass crops were encouraged to compare different grass species, varieties, and mixtures of species or varying seeding rates.

2.2. Producer Surveys

As per the signed Agreement, in order for a producer collaborator to receive land rent compensation, a completed survey was required from each producer at the end of each calendar year. Surveys were sent electronically to producers in the winter of 2010 and spring of 2011 and 2012. The survey was in a PDF format where producers could fill in the requested information and send it to OSCIA either as an email attachment or as a hard copy by mail. The information requested in the survey is provided in Appendix B. Surveys were collected from 25 of the 28 producers between 2010-2012. In total 43 surveys were completed. Surveys were not completed in cases where poor establishment in the first year resulted in the producer collaborator withdrawing from the program, or where producers were not requesting compensation.

2.3. Other Data collected

2.3.1. Producer Yield and Harvest Moisture

In addition to the survey, producers were required to submit accurate yield and harvest moisture information. To assist producers, methods were suggested by OSCIA regarding how to estimate yield. The most common method was based on the number of biomass bales per field, bale weight (typically weighed on a local truck scale), field area and an estimate of harvest moisture. In most cases harvest moistures were determined directly from a moisture sensor on the baler. A protocol was sent to all producers for determining harvest moisture using a kitchen scale (provided) and a microwave.

2.3.2. Data collected by OSCIA staff

Plots were visited on a regular basis by OSCIA staff In addition to collecting data described below, the interaction with producers provided the opportunity to discuss challenges faced by the producer and to gather additional feedback that could be used to supplement survey data. At the initial visit to each site the field was measured (using measuring wheel and GPS) to ensure yield accuracy and appropriate co-operator compensation.

OSCIA staff visited all plots in the fall, after biomass crop senescence between October and December in 2010, 2011 and 2012. In addition to fall measurements most plots were visited between May and July.

The following measurements were taken from a minimum of 4- 0.5 m^2 quadrants of seeded grasses (switchgrass, tallgrass prairie, big bluestem, indiangrass, etc.) or 4 randomly selected 5 m subsections of 2 rows of plants per plot of Miscanthus: plant count, tiller count, average culm height (cm) and tallest culm (cm), visual assessments of lodging severity (rating of 1-10), percent ground cover and ratio of grasses to weeds (out of 100).

Once the above measurements were collected, biomass (6 inch cutting height) was removed by hand harvest from the quadrant (seeded grass) or subsection of rows (Miscanthus). All biomass was removed from the area, including weeds. Immediately following hand harvest, samples of both seeded grasses and Miscanthus were weighed to determine "wet weight". Samples were then placed in a dryer at 80°C for a 48 hours. After 48 hours the samples were weighed, left to dry for 24 more hours and then weighed again. If the samples weights did not differ from the 48 hours weight measurement they were considered 100% dry and % moisture of "wet weight" amples calculated. Hand harvest "wet weight" yields were converted to kg dry matter ha^{-1} .

In 2010, 2011 and 2012, the above data were collected from the same randomly selected point in the plot. The point was identified using flags were left in the field or using a GPS with an accuracy of approximately ±3 m.

3. Project Co-operators

Twenty-eight co-operators took part in the project. While there were 28 co-operators, the analysis of the results has been broken down into 56 plots to capture different comparisons (species, ecovars, year of establishment, and planting method) investigated by the producers. The 56 plots are summarized in Table 3.1. Across the 56 plots, there is a wide geographic range represented in Ontario. Soils of the 56 plots vary to include most soil types from sand, loam and even several heavy clay soils. The land classifications of the 56 plots were 27% Class 1, 32% Class 2, 27% Class 3 and 14% Class 4 co-operator locations. Class 3 and 4 lands are limited by stoniness, shallow depth to bedrock, low fertility, highly erosive, excess water, and some with adverse climactic conditions.

Appendix C provides a summary of each co-operators agricultural background/involvement, choice of crop, interests in biomass crops and intended end market use.

Table 3.1- Summary of project co-operators field plots

Co-operator (last name)	County	Soil Type	CLI Land Class	Species	Variety	Year Established	Area (ac)
Abercrombie	Perth	Silt loam	1	Miscanthus	Austrian giganteus	2009	2
Abercrombie	Perth	Silt loam	1	Miscanthus	Austrian giganteus	2010	4.5
Abercrombie	Perth	Silt loam	1	Miscanthus	Austrian giganteus	2011	10
Abercrombie	Perth	Silt loam	1	Switchgrass	Cave-in-Rock	2011	8
Breault	Chatham-Kent	Sandy loam	2	Big Bluestem	Native ecovars	2012	15
Breault	Chatham-Kent	Sandy loam	2	Switchgrass/ Big bluestem/ Indiangrass	Native ecovars	2012	20
Breault	Chatham-Kent	Sandy loam	2	Tall Grass Prairie (with Forbs)	Native ecovars	2012	15
Buchanan	Chatham-Kent	Loamy sand	2	Switchgrass	Native ecovars	2011	8.2
Buchanan	Chatham-Kent	Loamy sand	2	Switchgrass/ Indiangrass	Native ecovars	2011	8.2
Buchanan	Chatham-Kent	Loamy sand	2	Tall Grass Prairie (with Forbs)	Native ecovars	2011	8.2
COFS	Oxford	Silt loam	1	Miscanthus	Nagara	2011	1
COFS	Oxford	Silt loam	1	Miscanthus	Austrian giganteus	2011	1
COFS	Oxford	Silt loam	1	Switchgrass	Cave-in-Rock	2011	1
COFS	Oxford	Silt loam	1	Switchgrass	Kanlow	2011	1
DeVisser	Bruce	Clay loam	3	Switchgrass	Cave-in-Rock	2010	9.6
DeVisser	Bruce	Clay loam	3	Switchgrass	Cave-in-Rock	2011	5
Dumanski	Norfolk	Sandy Loam	2	Tall Grass Prairie (with Forbs)	Native ecovars of Big Bluestem, Indiangrass and Switchgrass	2009	8.6

Co-operator (last name)	County	Soil Type	CLI Land Class	Species	Variety	Year Established	Area (ac)
Eggimann	Grey	Loam	4	Big Bluestem	Prairie View	2010	2.3
Eggimann	Grey	Loam	4	Switchgrass	Cave-in-Rock and Sunburst	2010	24.2
Eggimann	Grey	Clay loam	4	Switchgrass	Cave-in-Rock	2009 (2011 overseeded)	4.5
Eggimann	Grey	Clay loam	4	Switchgrass	Tecumseh II	2011	6.2
Fraser	Middlesex	Sandy loam	1	Miscanthus	Nagara	2008	0.15
Fraser	Middlesex	Sandy loam	1	Miscanthus	T-select	2008	0.15
Gaal	Stormont, Dundas and Glengary	Sandy loam	2	Switchgrass	Cave-in-Rock	2012	35
Hayes	Bruce	Clay loam and Sandy loam	2	Miscanthus	Nagara	2011	7.6
Hunter	Northumberlan d	Sand	4	Miscanthus	Nagara	2010	18.9
Lechowicz	Brant	Sandy loam	1	Switchgrass	Cave-in-Rock	2009	1.3
Malecki	Oxford	Loam	3	Miscanthus	Nagara	2011	13.2
Malecki	Oxford	Loam	3	Switchgrass	Cave-in-Rock	2011	6
McComb	Hastings	Loam	1	Miscanthus	Nagara	2010	0.8
Melien	Sudbury	Silt loam	3	Switchgrass	Cave-in-Rock and Forestburg	2012	11
Peeters	Kawartha Lakes	Loam	2	Miscanthus	Nagara	2011	5.3
Peeters	Kawartha Lakes	Loam	2	Switchgrass	Cave-in-Rock	2011	10.6
Renaud	Leeds and Grenville	Loam	4	Switchgrass	Cave-in-Rock	2011	5.3
Renaud	Leeds and Grenville	Loam	4	Switchgrass	Cave-in-Rock	2011	3.1

Co-operator (last name)	County	Soil Type	CLI Land Class	Species	Variety	Year Established	Area (ac)
Rural Lambton Stewardship Network	Chatham-Kent	Sand	2	Big Bluestem	Native ecovars	2007	18.1
Rural Lambton Stewardship Network	Chatham-Kent	Sand	2	Indiangrass	Native ecovars	2007	26.7
Rural Lambton Stewardship Network	Chatham-Kent	Sand	2	Switchgrass	Native ecovars	2007	2
Rural Lambton Stewardship Network	Lambton	Clay	3	Prairie Cordgrass	Minnesota native ecovars	2011	7.9
Rural Lambton Stewardship Network	Lambton	Clay	3	Switchgrass	Native ecovars	2011	8.6
Rural Lambton Stewardship Network	Lambton	Clay	3	Tall Grass Prairie (no Forbs)	Native ecovars	2011	8.9
Rural Lambton Stewardship Network	Lambton	Clay	3	Tall Grass Prairie (with Forbs)	Native ecovars	2011	8.9
Schwartz	Huron	Clay loam	2	Switchgrass	Blade Blackwell and EG1102/2101	2011	16.4
Schwartz	Huron	Clay loam	2	Miscanthus	Nagara	2011	1
Smith	Rainy River	Sandy loam	3	Miscanthus	Nagara	2011	13.6
Thompson	Leeds and Grenville	Sandy loam	4	Switchgrass	Cave-in-Rock	2010	29

Co-operator (last name)	County	Soil Type	CLI Land Class	Species	Variety	Year Established	Area (ac)
Tiessen, D	Essex	Clay loam (Clay)	3	Miscanthus	Nagara, M1 and an Illinois giganteus	2010	42
Tiessen, R	Essex	Clay	3	Miscanthus	Nagara and M1	2011	71.8
Timmermans	Oxford	Clay loam	2	Switchgrass	Cave-in-Rock	2011	43.7
Vanclief	Prince Edward	Clay loam	1	Miscanthus	Nagara	2010	0.9
Vanclief	Prince Edward	Clay loam	1	Switchgrass	Cave-in-Rock	2009	10.5
Vanclief	Prince Edward	Clay loam	1	Switchgrass	Cave-in-Rock	2006	63.5
Van De Slyke	Elgin	Sand	2	Tall Grass Prairie (with Forbs)	Native ecovars	2010	19
Young	Chatham-Kent	Clay loam	3	Miscanthus	Nagara, M1 and an Illinois giganteus	2011	26.1
Young	Chatham-Kent	Clay loam	3	Switchgrass	Carthage and Cave-in-Rock	2011	16.4
Young	Chatham-Kent	Clay loam	3	Tall Grass Prairie (with Forbs)	Native ecovars	2011	8.2
Total Biomass Acreage							725.1

4. Ontario biomass production insights

4.1. Field preparation

Field tillage preparation choices by producers were influenced by the crop grown the year prior to planting. Crops grown the year previous to grass establishment included: 38% soybeans, 20% hay/alfalfa/pasture, 18% corn, 9% wheat and the remaining 15% barley, canola, rye, unknown or left fallow. Where the previous crop was hay, alfalfa or pasture, deep tillage was performed by most producers. In plots where the previous crop was corn or wheat, disking and rolling were usually performed just prior to planting. No tillage was performed by most co-operators where grasses were planted following soybeans the previous year. Some co-operators also chose not to perform any tillage where the land had been left fallow and weeds controlled for 3-4 years or where due to the errosivity of the land. In addition to tillage, field preparation included a chemical burndown of weeds with a broad spectrum herbicide in the spring prior to planting for 80% of the field sites.

In reviewing co-operator feedback, field preparation was cited as the most important factor influencing weed control in subsequent years of establishment. Most producers were satisfied by their field preparation choices with the exception of some collaborators who attempted to establish into a field that had previously been hay, alfalfa or pasture. Comments were that weed control may have been improved by leaving the land fallow and performing more tillage and chemical burndowns or planting soybeans and establishing good control of any pasture grasses the year prior to planting.

In summary, field preparation was not crop, location or soil specific, but appeared to be specific to the cropping system being displaced. Soybeans are the preferred crop to precede establishment of biomass grasses as they are associated with little residue, the opportunity to use no tillage which enables a firm seedbed preferred by switchgrass and native tallgrass prairie, and are associated with primarily an annual weed complex that is less competitive and easier to control subsequent years. Conversely establishment of biomass grasses into hay, pasture or alfalfa can be difficult due to the need for tillage to control the previous crop, and the presence of a more competitive, more difficult to control perennial weed complex. Hay and pasture tends to be associated with soils/fields with lower land capability classes (i.e. "marginal" land) and often with higher erosion potential.   If production of these grasses is targeted to these soils/fields, then field preparation practices may need to be studied further to determine best management practices to ensure establishment. Such practices may need to consider chemical fallowing, or annual row crop production in years preceding biomass planting. Also, potential yield reductions and costs associated with high perennial weed pressure in grasses planted directly after a hay, pasture or alfalfa crop should be quantified.

4.2.Variety Selection

Varieties selected by producers are shown in Appendix D. Miscanthus varieties chosen by producers were; Nagara, M1 giganteus, Illinois giganteus, T-select, Amuri and Austrian giganteus. Miscanthus rhizomes and plugs for 14 of the 18 Miscanthus plots were purchased from New Energy Farms, Leamington. Co-operators received guidance from New Energy Farms on variety selection. Recommendations were based on their field trials in Leamington and collaboration on research trials by the University of Guelph and OMAF and MRA in Ridgetown and Elora, ON. The variety recommended by New Energy Farms for 13 of the 14 plots (either part of or the entire plot) was the Nagara variety. The Miscanthus planted at the remaining four plots were rhizomes of Austrian giganteus imported by the co-operator from ARGE Austrian Miscanthus, Stephanshart, Austria. ARGE is the supplier of a Miscanthus giganteus variety adapted to northern Austrian conditions.

Switchgrass varieties chosen by producers were; Cave-in-Rock, Carthage, Sunburst, Forestburg, Kanlow, Tecumseh II, Blackwell, EG 1102, EG 2101 and locally selected ecovars. Switchgrass varieties were selected by co-operators based on recommendations from early Ontario producers (Nott Farms, Clinton), seed companies (Hendrick Seeds, Inkerman and Ernst Conservation Seeds, Meadville, PA) and research trials (REAP Canada, St. Anne de Bellevue, University of Guelph and OMAF and MRA, Guelph). The Cave-in-Rock variety of switchgrass was selected by producers for 16 (either part of or the entire plot) of 24 switchgrass plots. Cave-in-Rock was selected by co-operators based on recommendations in switchgrass production guides (Samson, 2007), availability of seed (Nott Farms and Hendrick Seeds) and results of research trials by the University of Guelph and OMAF and MRA in Ridgetown and Elora, ON.

Tall grass prairie grasses planted by producers were Prairie View big bluestem (Ernst Conservation Seeds, Meadville, PA) and native ecovars of indiangrass, big bluestem, tall grass prairie mixtures with and without forbs and prairie cordgrass (native ecovars to Minnesota).

Some observations on variety selection can however be drawn from the demonstration plots at the COFS location. In direct comparisons of two switchgrass varieties (Kanlow vs. Cave-in-Rock) planted at the same time, with the same field preparation, seeding rate and weed control practices different varieties had significantly differing yields. The Kanlow variety had 86% greater yield compared to Cave-in-Rock in the second year of establishment. Kanlow is a high-yielding lowland variety that is adapted to more southern regions and typically not thought to be suited to winter conditions experienced in Ontario. In comparison Cave-in-rock is an upland variety better suited to Ontario conditions and risk of winterkill injury is much lower. Additionally, in direct comparisons of two the Miscanthus varieties (Nagara and Austrian giganteus) planted at the same time, with the same field preparation, seeding rate and weed control practices different varieties had significantly differing yields. The Nagara variety had 30% greater yield compared to the Austrian giganteus in the second year of establishment. These two varieties have not been directly compared before and based on fall visual observations the Austrian giganteus was taller and leafier than the Nagara. However, over winter the leaves on the Austrian giganteus all fell off, unlike the Nagara.

Producers selected varieties based on availability and the limited variety yields and comparisons reported from research trials conducted by University of Guelph/OMAF and MRA and commercial producers. As biomass crop markets evolve further producers will require further data to make informed decisions regarding variety selection. For example, the COFS site demonstrates that replicated variety field trials for switchgrass and Miscanthus are required to provide data on the yield and winterkill risk associated with switchgrass varieties.

4.3. Planting Methods, Timing and Establishment

Details of planting date, density, material planted (seed, rhizome or plug) and planting method used by co-operators are shown in Appendix D. All of switchgrass, indiangrass, big bluestem, prairie cordgrass and tallgrass prairie plots were planted by seed (further referred to as seeded grasses). The seeded grasses were planted by broadcasting (37.8%), no-till drilling with a conventional grain drill (21.6%) or a grass seed drill (40.5%) between mid-May and mid-June. The average seeding density was 9.3 ± 2.7 lbs ac^{-1}. Miscanthus plots were established by rhizomes (47.0%), plugs (29.4%) or a combination of both (23.5%). Rhizome planting densities ranged between 5, 000 and 16, 000 rhizomes ac^{-1} and plug planting densities were 4,500 to 16,000 plugs ac^{-1}. In four of the 18 Miscanthus plots both rhizomes and plugs were planted. In three plots different densities of the rhizomes and plugs were used and in one plot rhizomes and plugs were planted at the same density. Miscanthus planting methods of the 18 plots included 1 row (11%), 2 row (11%), 4 row (33%) and 1 and 4 row (6%) modified transplant planters, hand planting (22%), a specialized Miscanthus specific planter (11%) and a one row tree plug planter (6%) (Figure 4.1). Transplant planter modifications made by co-operators included increasing the cup size and lengthening the drop shoot. The press wheels were either modified (to leave no open space in the planting furrow) or co-operators had a person follow the planter and ensure the plants were closed in the furrow. Planting dates ranged between late April to mid-June, with 6 plots planted in July and one in early August.

Figure 4.1- Miscanthus rhizomes planted with a 4 row modified transplant planter

Seeded grasses were monitored for establishment from 2010 to 2012. Fall plant counts for 20 co-operators and 37 plots (data for two years is provided for three plots for a total of 40 observations) are presented in Table 4.1. Co-operators determined if establishment was successful by either a qualitative visual assessment of the crop or based on an establishment recommendation that a stand is successfully established if 10-32 plants m^{-2} can be found at the end of the year of planting (Samson, 2007). Plant counts for 11 of the 40 observations were less than 10 plants m^{-2} and are considered poorly established plots. The majority of the plant count observations (23 of 40) of the plots were within the range of 10-32 plants m^{-2} and considered successfully established. In six of the 40 observations plant counts were greater than 32 plants m^{-2} and deemed very successfully established. No trends in species, variety, seeding rate, year of establishment or planting method were identified as factors influencing seeded grass establishment success. Planting date was the most important factor identified by co-operators as impacting establishment success. This is confirmed with plant counts collected by OSCIA staff. Of the 11 observations of poorly established plots planting dates ranged from mid-June to mid-July while the very successfully established observations corresponded with planting dates of early April to late May. Overall, this project demonstrated that the earlier the planting the greater the establishment success of all seeded grasses. Refer to *Section 4.6- Corrective measures for poor stand establishment* for details of what actions co-operators took for manage poorly established plots.

Table 4.1- Average plant counts of seeded grasses in four $0.5m^2$ quadrants from 2010 to 2012

Co-operator	Species	Establishment Year	Age of Stand	Avg. Plant Count (#/$0.5m^2$)	Standard Deviation
Abercrombie	Switchgrass	2011	2	6	2.6
Breault	Big bluestem	2012	1	3	1.7
Breault	Switchgrass/Big bluestem/Indiangrass	2012	1	6	3.0
Breault	Tallgrass prairie with forbs	2012	1	5	1.0
Buchanan	Switchgrass	2011	2	9	7.0
Buchanan	Switchgrass/Indiangrass	2011	2	8	4.6
Buchanan	Tallgrass prairie with forbs	2011	2	6	3.9
COFS (Cave-in-Rock)	Switchgrass	2011	3	16	3.9
COFS (Kanlow)	Switchgrass	2011	3	11	1.0
DeVisser	Switchgrass	2011	1	7	4.5
DeVisser	Switchgrass	2010	2	5	2.7
Dumanski	Tallgrass prairie	2009	4	17	8.0
Eggimann	Big bluestem	2010	4	9	3.0
Eggimann	Switchgrass	2011	3	18	5.0
Eggimann	Switchgrass	2011	3	13	5.9
Eggimann	Switchgrass	2010	4	16	1.7
Gaal	Switchgrass	2012	1	0	0.0
Lechowicz	Switchgrass	2009	4	17	2.6
Malecki	Switchgrass	2011	1	15	5.4
Melien	Switchgrass	2012	1	18	10.2
Peeters	Switchgrass	2011	1	5	4.5
Peeters	Switchgrass	2011	2	4	7.1
Renaud	Switchgrass (Broadcast)	2011	1	5	2.8
Renaud	Switchgrass (Broadcast)	2011	2	5	4.1
Renaud	Switchgrass (No-till drilled)	2011	1	3	3.2
Renaud	Switchgrass (No-till drilled)	2011	2	3	2.8
RLSN (Bothwell)	Big bluestem	2007	6	19	1.0
RLSN (Bothwell)	Indiangrass	2007	6	11	2.1
RLSN	Switchgrass	2007	6	18	2.6

Co-operator	Species	Establishment Year	Age of Stand	Avg. Plant Count (#/0.5m^2)	Standard Deviation
(Bothwell)					
RLSN (Courtright)	Prairie cordgrass	2011	1	5	4.2
RLSN (Courtright)	Switchgrass	2011	1	1	1.5
RLSN (Courtright)	Tall grass prairie mixture	2011	1	0	0.0
RLSN (Courtright)	Tall grass prarie mixture with forbs	2011	1	2	2.1
Schwartz	Switchgrass	2011	2	3	2.1
Thompson	Switchgrass	2010	3	12	2.6
Timmermans	Switchgrass	2011	2	14	6.5
Vanclief	Switchgrass	2009	3	12	4.4
Vanclief	Switchgrass	2006	6	7	1.3
Young	Switchgrass	2011	1	1	0.7
Young	Tallgrass prairie	2011	1	1	0.8

Miscanthus plots were monitored for establishment from 2010 to 2012. Fall plant counts from sub-sampled quadrants were averaged and translated into a plant count per acre are presented in Table 4.2. Co-operators determined if establishment was successful by visual assessment of the plot. No quantitative method for estimating Miscanthus establishment success was used by co-operators. Of the 17 Miscanthus plots where planting density was recorded, the plant count at 14 plots was within 47-111% of the desired planting density. Three of the 17 plots were 1-37% of the desired planting density; these co-operators were McComb, Peeters and Smith.

Table 4.1- Miscanthus plot establishment plant count per acre from 2010 to 2012 compared to the initial planting density reported by the co-operator

Co-operator	Variety	Establishment Year	Age of Stand (yrs)	Plant count (#/acre)	Planting density reported by co-operator (#/ac)
Abercrombie	Austrian giganteus	2011	1	4077	5000
Abercrombie	Austrian giganteus	2011	2	3237	5000
Abercrombie	Austrian giganteus	2009 and 2010	2 and 3	3837	5000
Abercrombie	Austrian giganteus	2009 and 2010	3 and 4	3237	5000
COFS	Nagara	2011	1	5801	10000
COFS	Austrian giganteus	2011	1	6340	10000
COFS	Nagara	2011	2	5801	10000
COFS	Austrian giganteus	2011	2	6340	10000
Fraser	T-select	2008	4	4047	4500
Fraser	Nagara	2008	4	4047	4500
Fraser	T-select	2008	5	4047	4500
Fraser	Nagara	2008	5	4047	4500
Hayes	Nagara	2011	1	9173	5000-16000
Hayes	Nagara	2011	2	9712	5000-16000
Hunter	Nagara	2010	1	7338	11200-16000
Hunter	Nagara	2010	2	6367	11200-16000
Hunter	Nagara	2010	3	6475	11200-16000
Malecki	Nagara	2011	1	5531	5000
Malecki	Nagara	2011	2	5059	5000
McComb	Nagara	2010	1	4625	10000-14000
McComb	Nagara	2010	2	94	10000-14000
Peeters	Nagara	2011	1	1683	12000
Peeters	Nagara	2011	2	2428	12000
Schwartz	Nagara	2011	1	6475	Unknown
Schwartz	Nagara	2011	2	6205	Unknown
Smith	Nagara	2011	1	597	6000-10500
Smith	Nagara	2011	2	981	6000-10500
Tiessen,D	Nagara, M1 and Illinois giganteus	2011	1	6295	8000
Tiessen,D	Nagara, M1 and Illinois giganteus	2011	2	6175	8000
Tiessen,R	Nagara and M1	2011	2	6003	6000
Vanclief	Nagara	2010	2	7248	7300
Young	Nagara, M1 and Illinois giganteus	2011	1	4497	5000

Co-operators commented that planting equipment used for Miscanthus was suitable for the small acreage planted but that if larger acreage is required in the future Miscanthus specific planting equipment will need to be developed. Methods used were highly labour intensive and costly. The high labour requirements resulted in planting of over several days and weeks by all co-operators who planted over 1 acre of Miscanthus, with the exception of the two co-operators who used specialized Miscanthus planting equipment. As with the seeded grasses, planting date was one of the most important factors influencing Miscanthus establishment. When planting month was compared to a plant count/desired plant density ratio, planting dates of April/May, June and July were on average 0.80, 0.69 and 0.42 of the desired plant density. Delayed planting was negatively influenced Miscanthus establishment success. Early planting has lower weed pressure and competition for sunlight, soil moisture is higher and there is a longer growing period. Refer to section *4.6- Corrective measures for poor stand establishment* for details of what actions co-operators took for manage poorly established plots.

To assist in planting and Miscanthus establishment New Energy Farms has developed a new method for establishing Miscanthus called CEEDS™ (Crop Expansion Encapsulation Drilling System). CEEDS™ became commercially available in spring 2013. By encapsulating rhizome pieces in a standard size capsule they are able to significantly reduce the establishment cost (over 50%) and provide material with increased plant vigour (New Energy Farms, 2012). This product could significantly change Miscanthus planting systems. Further research is required on the effectiveness of this product in various locations in Ontario in the form of replicated research plots.

The lack of harvestable biomass in the initial planting year was considered a barrier for biomass crop production uptake for co-operators beyond this program. Adapting biomass establishment practices, to allow for additional revenue in the planting year was discussed by many producers during co-operator meetings (Refer to Appendix F for organized co-operator networking events). Further research is needed to assess the potential added value of planting a grain crop with the biomass crop in the first year. Two co-operators in this program sowed switchgrass into wheat or barley and were able to gain added income in the initial establishment phase. However the effect that the wheat canopy and any herbicides used on the wheat will have on switchgrass germination and establishment is unknown. A similar technique of planting Miscanthus with a corn crop is currently being researched at the University of Guelph-Ridgetown Campus. Miscanthus plants have demonstrated tolerance to corn herbicides and if Miscanthus and corn rows are intercropped some revenue could come from the corn crop, the Miscanthus establishes and weeds are controlled. Like sowing switchgrass with wheat or barley, the effect that the corn canopy will have on Miscanthus establishment requires further research.

4.4. Fertility

Soil tests of biomass fields were requested from co-operators in their Application of Interest to the program but were not required. Of the 28 co-operators, 7 provided recent soil test results. The results are summarized in Table 4.3. Relative to recommendations for forages in Ontario, a soil P test value below 10 ppm is rated low, and 10-25 ppm is rated medium (OMAFRA, 2009). Similarly forage recommendations indicate that a soil K test value below 80-100 ppm is rated low and 100-150 ppm is rated medium (OMAFRA, 2009). Of the 7 soil tests provided, test results are in the low range for P, K or both. In the absence of soil fertility recommendations specific to switchgrass, Miscanthus and tallgrass prairie forage recommendations are typically used, however, it is not yet certain that forage recommendations are appropriate, particularly given that nutrient removal rates are much higher for forage production. Of the 7 producers that provided soil test results, one co-operator expressed concerns that low P and medium K soil test results may be limiting their switchgrass and big bluestem yield potential and delaying stand establishment. Field plots managed by Eggimann received P and K fertilization in 2012 and 2013. In 2012, all 4 plots managed by Eggimann received 68 kg ac^{-1} of a 6-8-3 fertilizer blend and 46.5 kg ac^{-1} nitrogen fertilizer (form unknown). Fertilization in 2012 was based on soil test results from 2010. Further soil testing was done in the fall of 2012 and was used for determining 2013 nutrient requirements. Fertilizer rates used in 2013 and resulting yields have yet to be collected.

Table 4.3- Recent soil test results provided by seven co-operators

Producer	pH	P (Bicarb, ppm)	K (ppm)
DeVisser	7.5	8.0	160.0
Dumanski	6.7	32.0	85.5
Eggimann	7.5	5.7	108.5
Peeters	7.9	14.0	80.0
Renaud	7.2	19.0	90.0
Smith	6.7	8.0	146.0
Van De Slyke	6.9	111.6	71.8

Of the 21 co-operators who did not provide soil test results, two co-operators applied P and K fertilizer. P and K fertilizer applied was a N-P-K blend to one tallgrass prairie plot and one Miscanthus plot. The co-operator with the tallgrass prairie plot applied a corn blend fertilizer that was being applied to adjacent field in the spring of the third year of crop growth. The co-operator applied 112 kg ha^{-1} of 36.6-0-12.2. No comments were provided by the co-operator on the reason for this choice, however based on the lack of recent soil test results it is believed that this rate and blend was selected the ease of application to the adjacent tallgrass prairie field. The only Miscanthus plot that received P and K fertilizer was a second year plot that received 100 kg ha^{-1} of a 6-24-24 fertilizer blended for use on corn. Comments by the co-operator were that this was only expected for the second year of growth, would not be applied annually and was based on recommendations from another Miscanthus producer in Ontario. Out of 28 producers three provided P and K fertility to their biomass fields, one applied rates based on recent soil test results, one applied rates and the fertilizer blend already being used on farm on corn and the other based on another producers recommendations.

Nitrogen fertilization without P and K was applied by six co-operators to 10 plots between 2010 and 2012. Four plots received fertilizer for two years of the project for a total of 14 nitrogen fertilizer application observations. N fertilizer was applied to one plot in the initial planting year. In this instance switchgrass was sown into winter wheat. The wheat was fertilized 2 weeks prior to switchgrass seeding in May with 28% UAN (urea and ammonium nitrate, rate unknown). The six plots that were fertilized with urea in the second year of establishment were either switchgrass or tallgrass prairie. Application rates varied from 18-46 kg N ha^{-1} applied between mid-May and late August. Six established switchgrass plots were fertilized with 60-67 kg N ha^{-1}

in the form of urea between May and June. One established Miscanthus field was treated with mushroom compost in the spring to provide the crop with nitrogen and to control the inter-row weed pressure.

Producers based nitrogen fertility management decisions on recommendations from other Ontario biomass grass producers, production guides, research trials by the University of Guelph and OMAF and MRA and recommendations from the seed or rootstock suppliers. The decision to apply mushroom compost by the one co-operator was not based on requirements of the Miscanthus crop. This decision was made to use existing mushroom compost available to the co-operator and to provide weed control.

Co-operators commented that nitrogen fertilizer should be applied early in the season. Mid-summer application of nitrogen fertilization showed visual improvements in the crop but did not demonstrate yield benefits. No co-operator reported any increased concerns with lodging or yield benefits from addition of nitrogen fertility. In discussions with co-operators general comments were made that approximately 60-70 kg N ha^{-1} was the optimal rate of nitrogen fertilization on switchgrass. Co-operators believed that this rate would maximize yield, not induce any additional lodging and be the most cost effective rate. While Ontario based nitrogen response data for switchgrass, Miscanthus and tallgrass prairie is limited; the estimate of 60-70 kg N ha^{-1} corresponds to recommendations made by Nott Farms, Clinton, a switchgrass production guide for Ontario (Samson, 2007) and observations from Ontario field research. While 60-70 kg N ha^{-1} is probably a good general recommendation, it is anticipated that nitrogen rate requirements will vary with location, year, yield expectation, value of crop and other factors. In yield trials on spring harvested biomass grown at varying N fertilization rates at two locations (Ridgetown and Elora) in Ontario, switchgrass demonstrated significant yield increases with supplemental N fertility while Miscanthus yield did not increase with added fertilization. Complexities observed in general recommendations of field crop species, such as corn, may need to be developed for switchgrass, Miscanthus and tallgrass prairie. Further research will be required to develop crop specific fertilization recommendations of established crops as the biomass industry develops in different regions of Ontario.

The lack of supplemental nitrogen fertility on almost all biomass plots in the year of establishment is recommended for minimizing weed pressure and competition with the grass seedlings. If soil P or K is deemed to be low, P and K fertilizer should be applied in the initial planting year or prior to establishment. Beyond the establishment year, P and K fertility recommendations will depend on how the crop is managed (e.g. fall or spring harvest) and the nutrient concentration and yield which determines removal rates.

4.5. Weed Management

Analysis of weed management is broken down into methods in the year of establishment, second year of growth and established growth or main use phase (≥3 years). Weed management methods were classified as; no weed management, mowing, herbicide, mowing and herbicide, herbicide with some other method of weed management or other. Weed management methods reported from the 2010-2012 surveys are shown in Figure 4.2.

Of the 56 plots in the program, weed management methods for the establishment year were documented from 39 plots. No weed management in the establishment year was the practice used by co-operators on 11 plots. Mowing was the most common method (13 plots) of weed management followed by herbicide use (9 plots).

Depending on the extent of weed pressure across a field, mowing was either done on the whole field or only in areas of the field weeds were deemed to be a significant problem based on visual assessments by the co-operator over the growing season. Mower height varied by co-operator and mower used, however in all cases the mower was adjusted to the highest possible cutting height of approximately 6-18 inches. Mowing weeds occurred between May and mid-August above the height of the desired grasses. Co-operators reported challenges in deciding on optimal mowing time for controlling weeds and avoiding grass crop damage. One co-operator, who mowed only sections of switchgrass and big bluestem plots, leaving the remainder of the plot untouched, did not observe any visual differences in weed pressure in the fall of that initial establishment year.

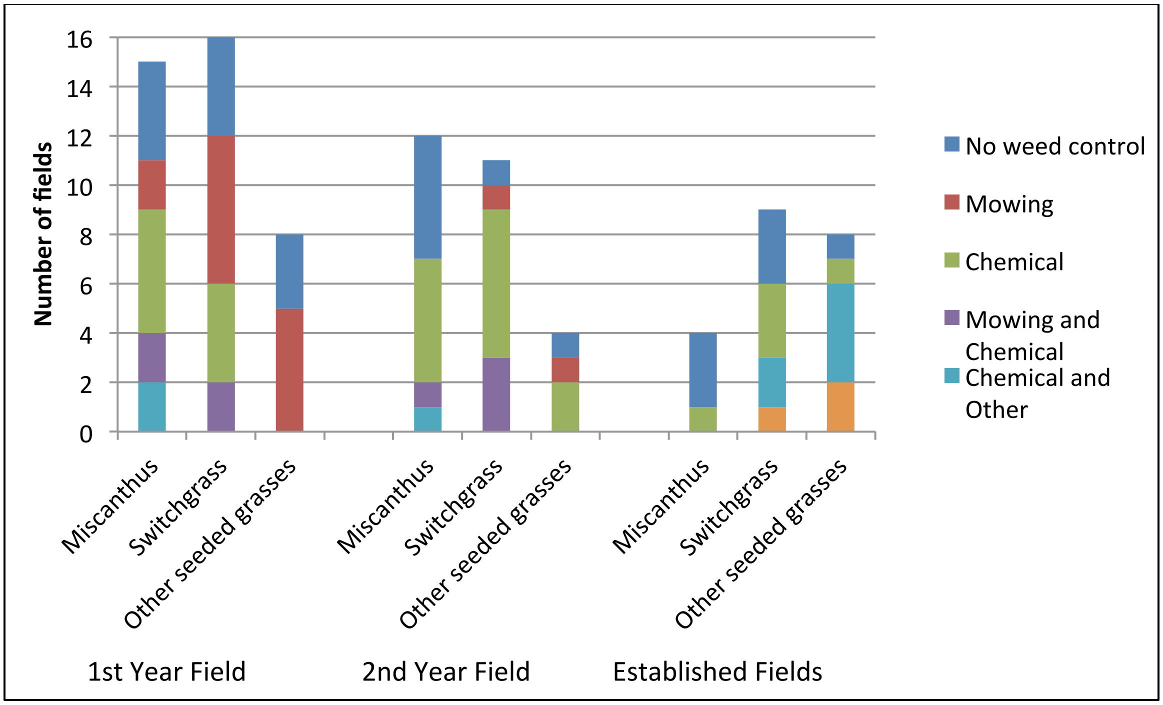

Figure 4.2- Summary of reported weed control methods of each biomass field from co-operator surveys (2010-2012) by level of establishment

The herbicides and rates used by co-operators in the establishment year are included in Table 4.4. There are currently no herbicides registered for use on Miscanthus, switchgrass and tallgrass prairie. Co-operators were required to base herbicide decisions on recommendations from other jurisdictions and from the limited herbicide evaluation studies conducted to date in Ontario. Co-operators used a wide range of herbicides. The herbicides used are currently registered for use on other crop species grown in Ontario and co-operator application rates and use patterns for Miscanthus, switchgrass and tallgrass prairie were similar to that used in crops currently on the respective herbicide labels.

Table 4.4- Chemical weed control herbicides used by co-operators from 2010-2012

Product	Rate (L ha^{-1})	Grass Species	Age of Stand (yrs)	Pre or post-emergence	Broadleaf (B) or Grass (G) weed control	Comments
Accent	5	Switchgrass	1	Pre	G	Good weed control of heavy flush of proso millet, possible switchgrass damage
Dual	1.5	Miscanthus	1, 2	Pre	G	Grasses not considered problem weeds in field that year
Glyphosate	4 and 7.5	Miscanthus	1, 2, 3	Pre	GB	Applied before desired grass emerged and after some early season grass weeds emerged, excellent control, risk is low with dormancy spraying
	*	Switchgrass	3	Pre	GB	
Primextra (Dual and Atrazine)	3.5 and 2.5	Miscanthus	1, 2	Pre and Post	GB	Pre-good control of broadleaves until late fall, Post-Used in areas of poor establishment of switchgrass, would not use in areas of good establishment, controlled all weeds except yellow nutsedge
2,4-D Amine	0.5	Miscanthus	1	Post	B	
	0.1	Switchgrass	1,2,3	Post	B	Rate was too cautious, little control
	0.1	Big Bluestem	2	Post	B	Rate was too cautious, little control
2,4-D	1.3-2.5	Miscanthus	1,2	Post	B	Good weed control
	0.1-1.7	Switchgrass	2,3,5	Post	B	Should have applied ester as recommended, broadleaf escapes in fall, reasonable control
	0.5	Tallgrass Prairie	2	Post	B	Did not kill weeds, only stunted them
2,4-D and Banvel	0.85 and 0.29	Miscanthus	2	Post	B	Controlled all weeds but yellow nutsedge
Atrazine	2.1	Miscanthus	1	Post	GB	
Atrazine and 2,4-D Amine	4 and 1.3	Miscanthus	2	Post	B	Good weed control
Atrazine and Estaprop XT (Dichloroprop-P and 2,4-D)	4 and 2.8	Miscanthus	2	Post	B	Good weed control
Banvel	0.29	Miscanthus	1,2	Post	B	Controlled all but yellow nutsedge

Product	Rate (L ha^{-1})	Grass Species	Age of Stand (yrs)	Pre or post-emergence	Broadleaf (B) or Grass (G) weed control	Comments
Basagran	2	Miscanthus	2	Post	B	Used to control yellow nutsedge not controlled by 2,4-D and Banvel
Buctril M (Bromoxynil and MCPA)	2	Switchgrass	2, 3	Post	B	Herbicide control is required in first three years of establishment
	2	Big Bluestem	3	Post	B	Herbicide control is required in first three years of establishment
Buctril M and Atrazine	4 and 2	Miscanthus	2	Post	B	
	4 and 2	Switchgrass	2	Post	B	
Dichloroprop-DX	*	Switchgrass	2	Post	B	Ineffective for dandelion control and poor weed control overall
Estaprop XT (Dichloroprop-P and 2,4-D)	2.6	Miscanthus	2	Post	B	Moderate control of broadleaves (mustard, dandelion, burdock)
	2.6	Switchgrass	2	Post	B	
MCPA	3	Miscanthus	2	Post	B	
PAR III (2,4-D, Mecoprop, Dicamba)	6.25	Switchgrass	2,7,8	Post	B	
	6.25	Big Bluestem	7, 8	Post	B	
	6.25	Indiangrass	7,8			
Refine SG and Estaprop XT	*	Switchgrass	2	Post	B	Good weed control especially dandelion and wild carrot

*-Unknown

Since the herbicides used by co-operators are already registered for use on existing crops, weed control efficacy of these herbicides has been well documented in Ontario and, in general, co-operator experience with herbicide efficacy in Miscanthus, switchgrass and tallgrass prairie was similar. In some cases, weed control efficacy was poorer than expected due to the fact that Miscanthus, switchgrass and tallgrass prairie are not aggressive competitors during the establishment year and the persistence of herbicides is not sufficient. In other cases, poor weed efficacy was reported due to herbicides application rates that were low compared to rates used on registered crops. Low rates were used due to co-operator concern about potential crop injury if label rates were used. Possible herbicide damage was reported by one co-operator who applied Accent herbicide (5 liters ha^{-1} pre-emergence) on switchgrass. Herbicide damage was not observed by the co-operator on switchgrass seedlings but was speculated that damage may have contributed to the poor emergence perceived by the co-operator in the initial establishment year. No other herbicide injury was reported by the co-operators in any other years or crops.

Other weed control methods used in the establishment year included the use of mowing and chemical control (4 plots), chemical control and “other” (2 plots). The “other” includes the application of mulch of mushroom and paper compost on one Miscanthus plot and inter-row scuffling on another Miscanthus plot.

For the second year of plant growth, weed management methods were reported from 27 of 56 plots. Herbicide use was employed on 13 plots and was the most commonly used method for weed management. The herbicides and rates used are included in Table 6.1. Compared to herbicide use in the established year, weed control efficacy was similar or better since 2nd year Miscanthus, switchgrass and tallgrass prairie stands tend to be more vigorous and competitive. In the second year of the stand, other methods of weed control included mowing (2 plots), mowing and chemical control (4 plots) and chemical and “other” (1 plot). The “other” was the application of a mulch of wheat straw (1/4 of the plot) and ground cardboard (remaining 3/4 of plot). This mulch was applied on the existing Miscanthus stand in the spring.

In the third year of the stand or older, weed management methods were reported from 14 of 56 plots. Management methods were reported for some plots for multiple years where the crop was 3 years or older. Weed management observations were recorded for three plots from 2010-2012 years and one plot from 2010-2011 for 21 weed management observations on established stands. Methods of weed control in the third year or older of stand establishment were chemical (5 observations), chemical and “other” (6 observations) and “other” (3 observations). The “other” were controlled burns of 3 plots from 2010-2012 of switchgrass, indiangrass and big bluestem biomass in the spring. This practice has been used to control weeds and encourage seed production of the native ecovars as markets for the harvested material continue to develop.

Overall, co-operators were able to adapt a wide range of herbicides available in Ontario and registered for use on other crop species to effectively control weeds in the Miscanthus, switchgrass and tallgrass prairie. Broadleaf weeds were controlled effectively by co-operators while grass weeds, especially perennial grasses, were not as easily controlled in the biomass crops. Grass weed pressure was more variable between fields than broadleaf weeds and was largely a function of the field history. Perennial grasses, particularly late emerging, were a challenge for producers to control late in the summer as crops became taller and more difficult to access with spraying equipment. Three co-operators (2 Miscanthus plots and 1 switchgrass plot) reported effective weed control by applying glyphosate before crop emergence. This method was effective at controlling early emerging weeds in the later emerging C4 switchgrass and Miscanthus crops. This method of weed control does present risks to producers with the potential to harm the Miscanthus or switchgrass but if done effectively and with precise timing effectively controls perennial broadleaf and grass weeds.

The weed pressure in the various plots was a function of field history. Co-operators cited field cropping history (i.e. previous 1-2 years) as the most important factor influencing weed control. Miscanthus, switchgrass and tallgrass prairie following an annual row crop tended to have a weed complex consisting of annual weed species which could be more easily and consistently controlled. As discussed previously, Miscanthus, switchgrass and tallgrass prairie following idle land, pasture, hay tended to have weed complexes consisting of perennial weeds that are much more difficult to control, particularly in the establishment year when Miscanthus, switchgrass and tallgrass prairie are not highly competitive. Co-operators commented that idle land, pasture, or hay were the previous crop, weed management may have been improved by leaving the land fallow for one year and using tillage and chemical burndowns for weed control during the fallow period, by planting glyphosate tolerant soybeans 1-2 years prior, intensive use of tillage and herbicide to control hay and pasture in the fall and spring prior to planting. Planting date was also cited as an important factor influencing weed control. Comments were that weed control may have been improved by earlier planting.

Weed control was considered by co-operators to be one of the most important factors influencing crop establishment, in addition to planting timing. As indicated above, despite the importance of weed control to biomass producers, there are no herbicides registered for weed control on biomass grasses in Ontario. Researchers at the University of Guelph (Dr. Francois Tardiff, Dr. John O'Sullivan, and Dr. Rene VanAcker) and OMAF and MRA (Mike Cowbrough) have collected herbicide efficacy and crop tolerance data (from 2007-2011) on the several herbicides registered for use on cereal crops and their ability to control broadleaf weeds in Miscanthus and switchgrass. The herbicides tested with good annual and perennial broadleaf control and good or excellent crop tolerance were Buctril M (or Badge, Mexitrol or Logic M), Estaprop Plus (or Dichloroprop-D or Turboprop) and Refine SG. Minor use registrations for Buctril M and Estaprop Plus have been submitted by Mike Cowbrough. At the time of writing this report no progress has been made in these submissions and no further research is being conducted by the University of Guelph or OMAF and MRA on herbicides for biomass crops. A letter of support was submitted with this application by the authors of this report and can be reviewed in Appendix E.

4.6. Corrective measures for poor stand establishment

Producers typically assessed stand establishment success in the spring of year two. Delayed planting date and increased winterkill were the most common cause of stand failure reported by co-operators in all of the biomass crops. Delayed planting resulted in increased weed pressure on the establishing crop and increased competitions for sunlight, lower soil moisture and a shorter growing period. Refer to section *4.3- Planting Methods, Timing and Establishment* for details of how establishment success was determined by co-operators.

For Miscanthus six out of 14 co-operators assessed their second year stands as inadequate and requiring corrective measures. Of the six, only 3 co-operators decided to proceed with corrective measures to improve stands. Two co-operators filled in gaps in the Miscanthus stand with new Miscanthus transplant plugs, a process often referred to as "stitching". These two co-operators did this later in the year of establishment when it was observed that initial Miscanthus plantings of Miscanthus transplants/rhizomes did not survive. Another co-operator did the stitching procedure using plugs and rhizomes the following year, in the second year of growth. Stitching was completed manually or using a modified transplant planter. Of the six, three co-operators did not fill in gaps in due to poor weather conditions, lack of time due to competing activities on the farm, or a lack of perceived benefit. Stitching of Miscanthus stands tends to be a labour and time intensive process. The three co-operators that stitched Miscanthus stands reported little to no success. Miscanthus plugs planted later in the year of establishment did poorly due to dry soil conditions and increased risk of winterkill due to small plant size achieved prior to onset of winter. When Miscanthus stitching took place in the second year of establishment observations it was observed that rhizomes were generally not as successful as were transplants in competing with surrounding established plants. In either case stitched Miscanthus plants were not vigorous due to competition. Producers largely questioned the value of stitching given the limited success of stitched plants and the high labour and propagule costs associated with the procedure

Five out of 24 switchgrass plots and one out of three big bluestem plots had poor stand establishment and the co-operator deemed that they required corrective measures. Existing plots were overseeded with the same variety as the initial planting at 8-9 lbs ac^{-1} with the exception of one switchgrass plot that was initially planted with three different varieties (Blade Blackwell and EG1102/2101) was overseeded with the Cave-in-Rock variety. At one switchgrass plot further corrective action was taken. Weeds were controlled chemically (glyphosate and 2,4-D) and the weeds were mowed and baled in June three years after initial establishment. A new switchgrass variety (Tecumseh II) was broadcast seeded onto the field at 12 lbs ac^{-1}.

Plots were re-seeded either in the second or third year of the stand. Of the switchgrass and big bluestem plots overseeding re-establishment efforts were not reported to have been problematic and were considered successful. Where further corrective action was taken (chemical control and seeding of a new variety) the co-operator did not consider re-establishment a success. Delays in planting from delayed chemical control and a 10 day wait period following chemical control resulted in mid-June planting which the co-operator felt was too late for his area. Early planting between May and early June allows for a longer growing season, higher soil moisture and chemical and mechanical (mowing) weed control of early broadleaf and perennial weeds contributed to successful stand establishment and re-establishment.

4.7. Insect and disease pressure

No biomass producers in this program observed any significant insect or disease damage on their biomass grasses from 2010 to 2013. Insect damage was observed on Miscanthus at the COFS site (Figure 4.3) late in August, 2012 but appeared to be on the older leaves lower on the plant, isolated mainly to the leaf tips and margins. It is suspected that the damage was caused by armyworm. No insect damage was observed on switchgrass at the COFS site nor on Miscanthus in 2013. The damage observed in 2012 appeared to be worse on the Austrian giganteus clone than on the Nagara clone, but in either case it is unlikely that yield was negatively affected. The lack of observed insect and disease pressure by co-operators in this project is consistent with the observation by producers and researchers from other regions that there are currently few insect and disease pests of economic concern to Miscanthus, switchgrass and tall grass prairie. However, as acreage of these crops increase in Ontario monitoring of insect and diseases is required.

Figure 4.2- Insect damage to Miscanthus plants observed in Woodstock, ON in 2012

4.8. Lodging

Lodging of perennial grass biomass stands is a concern because lodging can negatively impact yield, biomass quality and harvest efficiency. The extent of the impact is presumably related to the degree of lodging and recovery from lodging that occurs. Based on observations in the present project, Miscanthus, switchgrass and tallgrass prairie all have the potential to lodge.

Switchgrass lodging was observed by OSCIA staff at three co-operator locations and six plots. Lodging of one switchgrass plot occurred in the first 3 years of establishment and two plots in the in the first 2 years of establishment. Lodging of switchgrass was observed at 3 plots established stands (≥3 years). In all cases lodging was isolated to small areas between 1m^2 to 10 m^2 of the field and occurred in summer months and fall following high rainfall events especially in 2012 where rainfall events across the province were less frequent and higher intensity than observed in 2010 or 2011. Co-operators did not believe that the observed switchgrass lodging affected harvestable yield.

Lodging of Miscanthus was observed at one of 18 sites in 2011 and at six of 18 sites in 2012. In 2011, lodging was restricted to Nagara variety (Figure 4.4). Lodging for this variety was severe 40-80% of the stems across the field lodged. In 2011, no lodging of the T-select variety was observed. Lodging in 2012 occurred at the Malecki, Hunter, Hayes, Fraser/Pieper, COFS and Abercrombie sites in Nagara and Austrian giganteus varieties. Lodging resulted in bending of 10-30% of stems at all locations, except the Malecki site where more severe bending occurred of between 10-50% at the sampling locations. As with switchgrass, lodging in Miscanthus tended to occur mid-summer. No co-operators reported lodging as a factor contributing to reduced yield potential in Miscanthus.

Figure 4.4-Lodging observed in Miscanthus plots in 2012

Of the 14 tall-grass prairie species plots, lodging was observed at two plots between 2010-2012. Established indiangrass was significantly lodged at one location following seed removal in 2012. OSCIA staff observed that over 90% of the material was below the 4-6 inches commonly left as stubble to allow for drying of the crop overwinter (See section *4.11. Harvesting Equipment Requirements*). As a result the co-operator harvested (cut and baled) the biomass in the fall to within 3 inches of ground level. The biomass was harvested at ~ 15% moisture in the fall and stubble was not required to assist in drying in the spring. One big bluestem plot also lodged in small areas between 1m^2 to 10 m^2 of the field in the first, second and third years of establishment. The co-operator did not report any concerns with yield losses as a result of this lodging.

Incidence of lodging tended to be associated with increasing rate of nitrogen fertilizer, intensive, high rainfall events, lush stands associated with above average precipitation, and, in the case of Miscanthus, the variety Nagara. The variety specific lodging of Miscanthus that occurred in 2011 is consistent with a University of Guelph research trial in Elora, ON in 2011. The same Nagara variety demonstrated severe lodging, while other varieties in that trial had minimal to no lodging. Future efforts to develop nitrogen rate recommendations for biomass grass species will need to consider impacts of nitrogen fertilization on lodging. While higher nitrogen rates tended to be associated with lodging, it is interesting to note that the worst case of lodging in Miscanthus was observed where no nitrogen fertilization occurred, indicating that variety effects on lodging incidence are also a very important factor.

4.9. Harvest moisture

Of the 38 harvest yield estimates provided by co-operators, 29 yield estimates were spring harvested between late April and mid-June with one plot harvested in February. Typically producers would harvest after 1-2 days of sunshine since, under humid/wet conditions biomass moisture content will increase potentially to a level that could cause storage losses. Seven of the 38 reported yield estimates were from plots that were harvested in the fall (October) and two were harvested in late-August and September.

Average harvest moistures reported by co-operators are summarized in Table 4.5. In the spring of 2010 and 2011, spring harvested Miscanthus had approximately double the moisture content of the other seeded grasses. Differences in moisture contents reported in this study may be due to differences in moisture retention of Miscanthus compared to switchgrass, but since results are confounded with weather prior to harvest, harvest dates, and other factors, it cannot be conclusively stated that harvest moisture differences are due to species differences. Moisture results from research trials of side-by-side plots of Miscanthus and switchgrass (Deen, data unpublished) harvested in the spring would suggest that moisture contents would be similar. As was observed in the spring of 2012 when all grasses had similar moisture contents between 8.1 and 8.8%.

Co-operators all reported being satisfied with the moisture the grasses were baled at and no problems with storage were reported.

Table 4.5- Summary of co-operator reported moistures (%) at harvesting for Miscanthus, switchgrass and other seeded grasses (tallgrass prairie, big bluestem and indiangrass) for harvesting of the 2010-2012 growing season biomass.

Growth Year	Harvest Timing	Percent Moisture (± SD*)		
		Miscanthus	Switchgrass	Other seeded grasses
2010	Spring	10.0	6.1	
2011	Spring	12.8 ± 3.95	6.8 ± 0.87	11.9 ± 5.00
2012	Fall	18.0	16.0 ± 1.27	15.1 ± 0.57
	Spring**	8.1 ± 1.09	8.4 ± 0.88	8.8

*- Values not followed by standard deviations were not replicated
**- Harvested the 2012 crop in the spring of 2013

As indicated above, spring harvest typically occurred between April and June. Fall harvest is often not possible due to high moisture content and resulting potential problems with storage losses. Questions have been raised by producers regarding how moisture content of the grasses decreases over the winter. This was of interest for co-operators who may potentially wish to harvest biomass in snow free areas during the winter months or early spring on frozen soil.

Periodically over the 2012-13 winter, biomass samples of Miscanthus were collected (and moisture content measured. Sampling was conducted during snow and rain free periods to ensure that there was no surface moisture on the Miscanthus samples. Samples collected in 2013 from Elora (2 varieties) and Drumbo demonstrate a gradual decrease in moisture content through the winter and early spring months (Figure 4.5). It was not until mid-April that moisture contents decreased to the averages reported by co-operators in spring harvests that same year, indicating that mid-winter harvest of Miscanthus for dry storage may not be feasible.

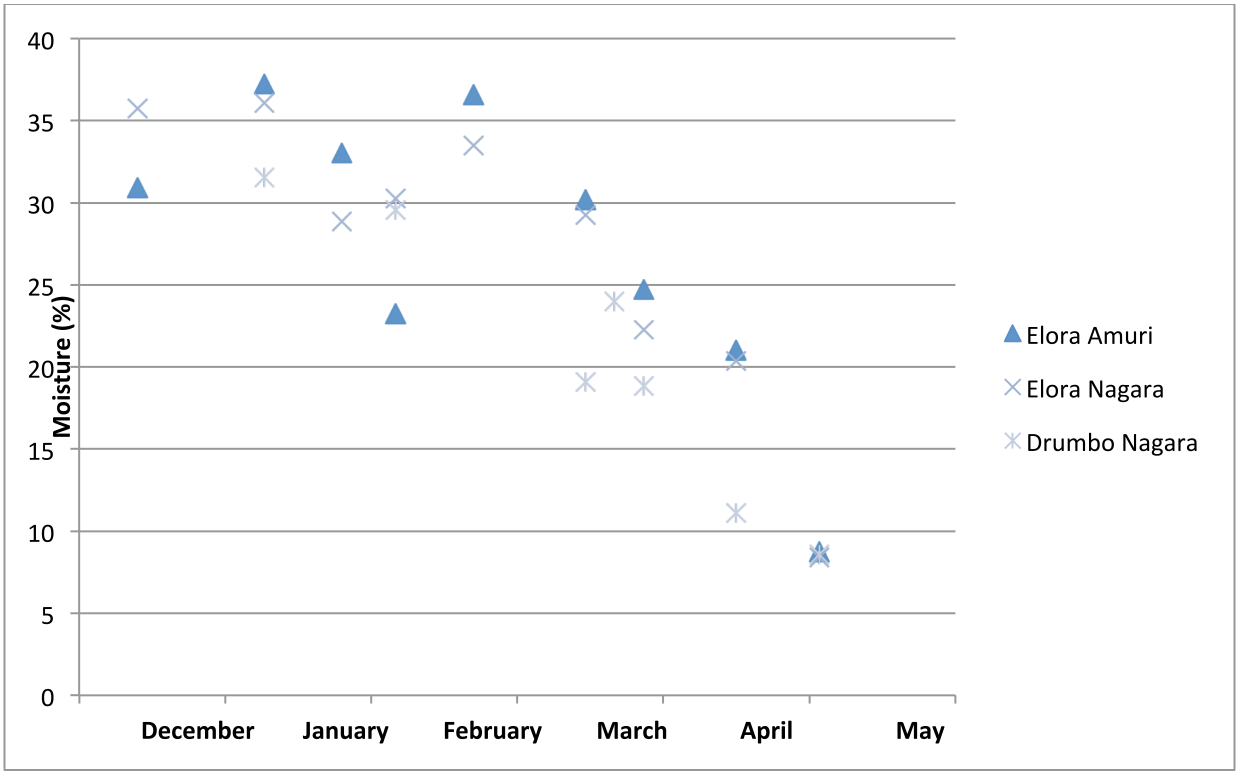

Figure 4.5- Miscanthus moisture content (%) measured over the winter months, 2013, Elora and Drumbo, ON.

The range of harvest moistures observed by the co-operators is consistent with similar trials in Ontario where the spring harvested moisture content of Miscanthus and switchgrass was 5-15% (Engbers, 2012; Samson, 2007). Previous research has also shown that delaying harvest timing from fall to spring significantly reduces the moisture content of the harvested material. Research trials in Ontario have reported that switchgrass and Miscanthus harvested in the fall can contain between 35-42% moisture, almost three times that in the spring (Engbers, 2012). From sampling Miscanthus in Elora and Drumbo there is no harvest moisture benefit to producers to harvesting in the winter and early spring.

Harvesting biomass grasses at low moisture content is potentially important for three main reasons. First, in Ontario it is recommended that hay bales be below 15-18% depending on bale shape and size (OMAFRA, 2009) in order to reduce spoilage and limit heating and resulting quality reductions. This same guideline is currently applied to biomass bales, however, co-operatorsco-operators did indicate that allowable moisture levels for biomass bales may be higher since low N concentrations may limit spoilage and heating. Currently the relationship between biomass moisture content and storage losses is not well understood. Second, low moisture contents may reduce drying costs to the end user (Samson, 2007). Third, low moisture contents may minimize transport costs of the biomass to the end-user.

The present study demonstrates that low harvest moisture contents are easily achievable under Ontario conditions. At spring harvest moisture contents storage losses are not a concern. Fall harvest or mid-winter harvest of standing Miscanthus may or may not be feasible if a dry storage system is targeted. Further research is required to determine moisture x storage loss relationship for grass biomass bales.

4.10. Yield

Yields and harvest moistures were reported by co-operators from the 2010 to 2012 growing seasons. Of the 56 plots in the program 29 plots were harvested at least once during the 3 year program for 37 harvest yield observations and harvest moistures included in Table 4.6. The remaining 27 plots were not harvested. Fields were not harvested either due to poor establishment resulting in the co-operator deciding not to harvest the biomass (17 plots) or the co-operator deciding to remove the plot (10 plots).

Table 4.6- Co-operator reported yields (t DM ac-1 and t DM ha-1) and moisture at harvests between 2010 and 2012

Survey Year	Co-operator	Species	Variety	Year of establish-ment	Age of crop (yrs)	Yield (t DM ac^{-1})	Yield (kg DM ha^{-1})	Moisture (%)
2010	Abercrombie	Miscanthus	Austrian giganteus	2009	2	2.10	5038	10.00
2011	Abercrombie	Miscanthus	Austrian giganteus	2010	2	1.25	3012	11.00
2012	COFS	Miscanthus	Nagara	2011	2	2.38	5716	8.50
2012	COFS	Miscanthus	Austrian giganteus	2011	2	1.83	4398	8.60
2012	Malecki	Miscanthus	Nagara	2011	2	1.97	4718	6.50
2011	Tiessen, D	Miscanthus	Nagara, M1 and an Illinois giganteus	2010	2	4.10	9840	17.00
2011	Vanclief	Miscanthus	Nagara	2010	2	8.26	19822	7.50
2011	Abercrombie	Miscanthus	Austrian giganteus	2009	3	5.44	13051	15.50
2012 ***	Hunter	Miscanthus	Nagara	2010	3	3.28	7872	18.00
2012	Tiessen, D	Miscanthus	Nagara, M1 and an Illinois giganteus	2010	3	7.92	19008	8.85
2011	Fraser	Miscanthus	Nagara	2008	4	8.77	21048	*
2011	Fraser	Miscanthus	T-select	2008	4	8.50	20400	*
2012 ***	Buchanan	Switchgrass	Native ecovars	2011	2	0.59	1409	16.70
2012	COFS	Switchgrass	Cave-in-Rock	2011	2	0.79	1901	8.66
2012	COFS	Switchgrass	Kanlow	2011	2	1.48	3552	7.67
2011	Eggimann	Switchgrass	Cave-in-Rock and Sunburst	2010	2	1.03	2482	6.00
2012 ***	Malecki	Switchgrass	Cave-in-Rock	2011	2	3.42	8208	10.00
2011	Thompson	Switchgrass	Cave-in-Rock	2010	2	1.30	3120	*
2012	Timmermans	Switchgrass	Cave-in-Rock	2011	2	0.11	263	9.83
2010	Vanclief	Switchgrass	Cave-in-Rock	2009	2	0.00	0	
2012	Eggimann	Switchgrass	Cave-in-Rock and Sunburst	2010	3	0.66	1578	8.84
2011	Eggimann	Switchgrass	Cave-in-Rock	2009 (2011 overseeded)	3	0.63	1502	6.00

Survey Year	Co-operator	Species	Variety	Year of establish-ment	Age of crop (yrs)	Yield (t DM ac^{-1})	Yield (kg DM ha^{-1})	Moisture (%)
2011	Lechowicz	Switchgrass	Cave-in-Rock	2009	3	0.98	2345	*
2011	Vanclief	Switchgrass	Cave-in-Rock	2009	3	0.62	1483	7.50
2012	Eggimann	Switchgrass	Cave-in-Rock	2009 (2011 overseeded)	4	0.66	1588	8.84
2012	Vanclief	Switchgrass	Cave-in-Rock	2009	4	0.62	1483	7.50
2010	Vanclief	Switchgrass	Cave-in-Rock	2006	5	2.75	6609	6.05
2012 ***	Rural Lambton Stewardship Network	Switchgrass	Native ecovars	2007	6	3.20	7674	14.50
2011	Vanclief	Switchgrass	Cave-in-Rock	2006	6	3.32	7970	7.50
2012	Vanclief	Switchgrass	Cave-in-Rock	2006	7	3.32	7973	7.50
2012 ***	Buchanan	Switchgrass / Indiangrass	Native ecovars	2011	2	0.59	1409	16.70
2011	Eggimann	Big Bluestem	Prairie View	2010	2	0.38	902	6.00
2012	Eggimann	Big Bluestem	Prairie View	2010	3	0.27	656	8.84
2011	Rural Lambton Stewardship Network	Big Bluestem	Native ecovars	2007	5	2.46	5904	18.00
2012	Rural Lambton Stewardship Network	Big Bluestem	Native ecovars	2007	6	2.29	5486	14.70
2011	Rural Lambton Stewardship Network	Indiangrass	Native ecovars	2007	5	2.64	6336	10.50
2012 ***	Rural Lambton Stewardship Network	Indiangrass	Native ecovars	2007	6	2.00	4806	15.50
2011**	Dumanski	Tall Grass Prairie (with Forbs)	Native ecovars of Big Bluestem, Indian Grass and Switchgrass	2009	3	2.55	6128	13.00

*-missing information

**-late summer harvested
***- fall harvested

Yields of the 29 plots were recorded following a spring harvest while one plot was late summer harvested (late August) and six plots were fall harvested (October-November). No producers harvested in the year of establishment and all reported yields are from the second year of establishment and the yield is ~70% of full yield potential or once the crop has reached full yield potential in the third year and beyond (Clifton-Brown and Lewandowski, 2002; Heaton et al., 2008; Pyter et al., 2009). Yields presented in Table 4.6 vary by location, year and variety and have been summarized in Table 4.7. Yield observations of the same species either in the second year of establishment or the established stand were highly variable. Second year Miscanthus, second and established switchgrass and established big bluestem had standard deviations greater than 50% of the average yield.

Table 4.7- Yield averages of co-operator reported yields harvested in the fall

Species	Age of crop (yrs)	Yield (kg DM ha^{-1} ± SD)
Miscanthus	2	7506 ± 5831.7
	≥3	18377 ± 3651.1
Switchgrass	2	2211 ± 1282.1
	≥3	3615 ± 2965.4
Indiangrass	≥3	5571 ± 1081.9
Big bluestem	≥3	4015 ± 2916.8

Spring harvested co-operator reported yields were compared to hand harvested yields estimates from samples collected by OSCIA staff and are presented in Figures 4.3 and 4.4. Hand harvested yield estimates were collected from a minimum of 4- 0.5 m^2 quadrants of switchgrass or a minimum 8 plants at 4 randomly selected subsections of 2 rows of Miscanthus per plot in the fall. Plants were cut to ~6 inches from the ground in the fall and dried to obtain kg dry matter (DM) sample $area^{-1}$. Switchgrass yields were converted to kg DM ha^{-1} using the 0.5 m^2 area while the average plant weights were converted into kg DM ha^{-1} using the plot establishment plant count per acre in Table 4.2. Of the 29 spring harvested plot yields reported by co-operators 20 observations were matched with a hand harvested yield for 10 Miscanthus observations and 10 switchgrass observations.

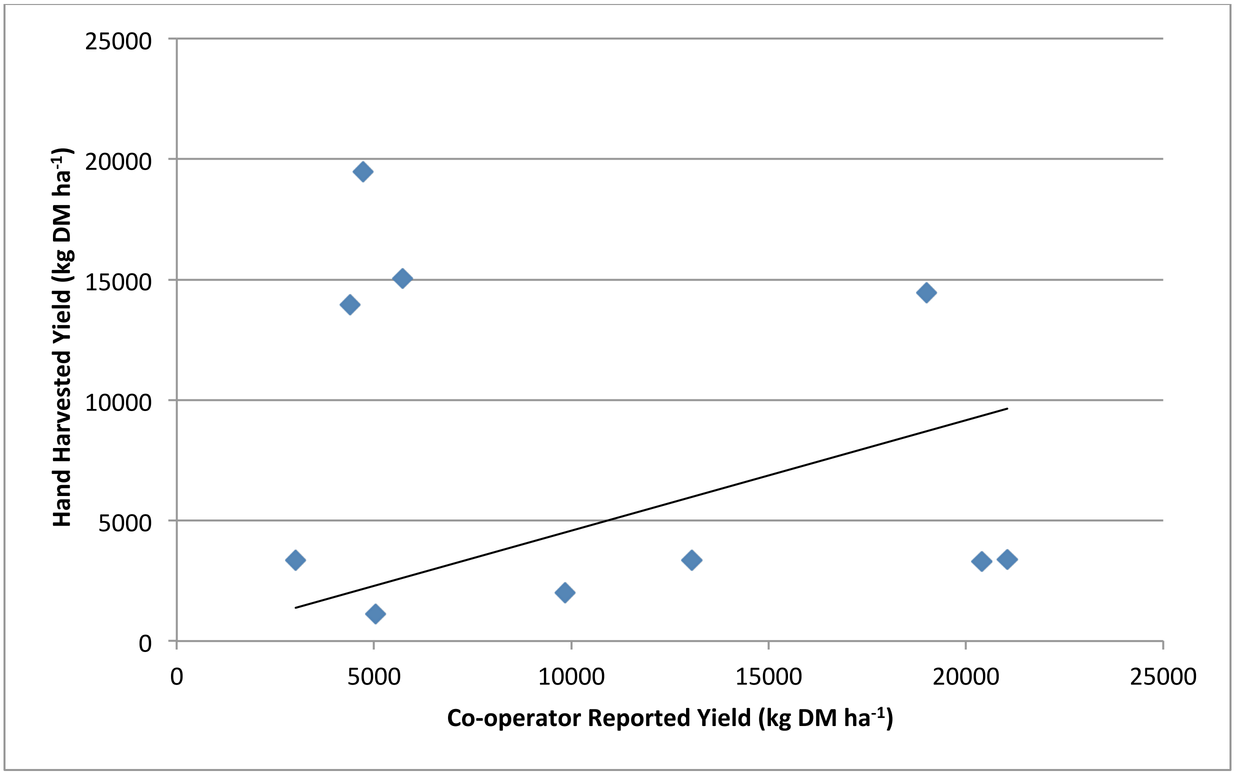

Figure 4.6- Hand harvested yields (kg DM ha^{-1}) compared against co-operator reported yields (kg DM ha^{-1}) for 12 Miscanthus yield observations in the second year and of establishment and fully established stands (≥3) combined

Miscanthus yields reported by co-operators tended to be greater than yield estimates based on hand harvests of random sample areas across the field (Figure 4.6). While it is unclear what the underlying cause of discrepancy is, several possibilities should be considered. It is possible that yield variability across a field is high and sampling just four points in the field may not enable estimation of mean yields. However, if this indeed were the main cause of the discrepancy it is expected that 50% of hand harvest yield estimates would be greater than co-operator estimates and 50% would be less than co-operator estimates. This does not seem to be the case since there are a greater number of occurrences where hand harvest estimates are less than co-operator estimates (Figure 4.6). The possibility that co-operator estimates of yield may be an overestimate of actual yields needs to be considered as a cause of the discrepancy. Co-operators may have overestimated yield either by overestimating bale weight or under estimating bale moisture. If both occur the errors would compound. In some cases bale weight provided by co-operators were based on estimate and not an actual scale weight. For bale moisture determination, co-operators were asked to collect a subsample of at least 3 different bales and use a microwave method of moisture determination, with a protocol and scale provided. Instead of using the provided protocol, all co-operators reported harvest moistures directly from the moisture sensors on the balers and an average estimated by the custom baler operator. Error in moisture determination may have resulted from inaccuracies of the baler moisture sensor when used to measure Miscanthus moisture, or from biases in average moisture estimation provided by the custom baler operator. Differences in hand harvested and co-operator reported yield estimates might also be due to differences in cutting height. Hand harvested yield estimates were based on a cutting height of ~6 inches while the cutting height used by co-operators was more variable and may have been less than or greater than 6 inches. While co-operators reported also cutting to ~6 inches when OSCIA staff visited plots after plot harvesting was completed, it was observed that in any given field the cutting height varied from less than 1 inch up to 6 inches, with the average cutting height probably less than 6 inches.

Switchgrass yield estimates reported by co-operators tended to correspond more closely to hand harvested yield estimates (Figure 4.7). Hand harvested yields tended to be higher (y=1.36x) than reported yields, but it should be noted that hand harvested yields are based on a fall harvest timing and co-operator reported yields are based on a spring harvest timing. A 25-30% overwinter loss has been reported in previous studies.

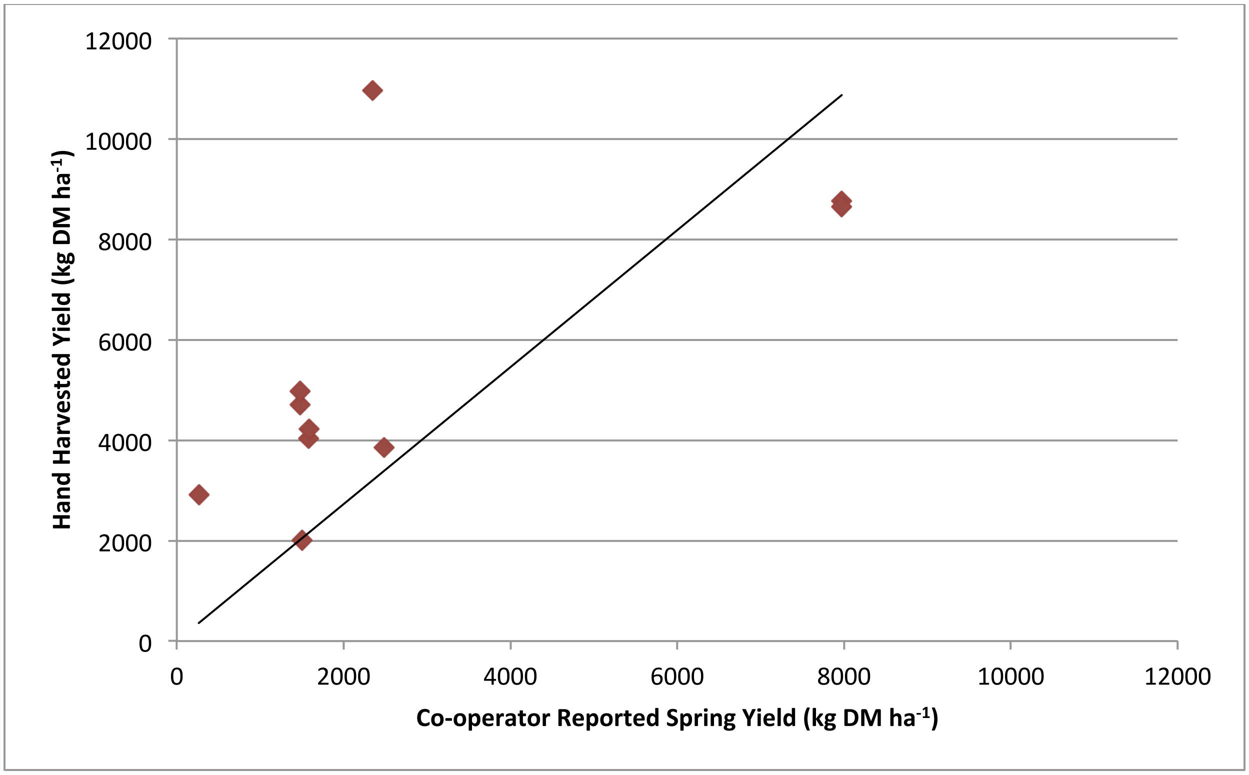

Figure 4.7- Hand harvested yields (kg DM ha^{-1}) compared against co-operator reported yields (kg DM ha^{-1}) for 17 switchgrass yield observations in the second year and of establishment and fully established stands (≥3) combined

Co-operators were asked for feedback on whether yields achieved, met or exceeded their expectations at the outset of the project. Co-operators generally commented that stands were slower to establish than expected and time to achieve reasonable yields took longer than anticipated. Co-operators often commented that biomass yield was lower than anticipated. Lower than anticipated yields were often attributed to 1) poor establishment resulting from late planting, dry soil, or poor weed control, 2) cooler more northern climates and 3) poor quality soils taking longer to reach full yield potential. Seventeen plots, of which sixteen were in the second and third year of growth, were not harvested at all during this program despite plans by all co-operators to have harvested by the spring of 2012. Co-operators who managed those 16 plots reported that there was not enough biomass to warrant harvesting the biomass, especially in cases where the co-operator had not yet determined an end use market for the biomass.

Average co-operator estimates of yield of crops three years and older (Table 4.7) can be compared to Miscanthus and switchgrass yields from research in Ontario. Established (≥ 3 years) Miscanthus plots achieved an average yield of 18 t ha^{-1}. It has been estimated that Miscanthus produced on fertile soils can achieve 30 t ha^{-1} while on shallow, droughty, cold or waterlogged soils would achieve 10 t ha^{-1} (Kludze et al, 2011). The average switchgrass yield reported by co-operators on stands 3 years and older was 3.6 t ha^{-1}. Compared to switchgrass yields of 8-12 t ha^{-1} reported elsewhere (e.g. Samson, 2007), co-operator yields were much lower. Switchgrass plots in this program may have represented more northern locations with shorter growing seasons and marginal soils than addressed in research programs in Ontario to date. Further research is required to determine the time required to reach full yield potential of the different grasses, and switchgrass in particular, across Ontario.

4.11. Harvesting Equipment Requirements

Equipment used for harvesting seeded grasses included; hay and disc bines, hay rakes, small square, round, large square and high density balers (Figure 4.8). Miscanthus harvesting equipment used included; discbines, a self-propelled forage harvester and large square balers (Figure 4.9). Switchgrass and tall grass prairie plots were cut by producers to 3-6 inches from the ground and Miscanthus was harvested 2-4 inches from the ground. Balers were chosen based on what was most readily available and the desired end use market. For biomass being used on farm as mulch, small bales were preferred for convenience. Round balers with net wrapping were used to harvest some plots, however, as discussed below, large square balers was the baling implement of choice for most co-operators. The bale weight of a large square bale ranged from 340-550 lbs with bale sizes of 3 ft x 3 ft x 6-8 ft. Co-operators either contracted custom balers to harvest the biomass or used their existing machinery. A high density square baler (e.g. Krone Big Pack 1290XC) was used by a two Miscanthus producers in 2013. By using a high density baler, bale weight can be increased from 340-550 lbs to 750-800 lbs.

Figure 3.8- Switchgrass overwintered in windrows (A), baled (B and C) and stored in field (D)

Feedback on harvesting equipment for the three biomass crops in this study can be divided into three categories; cutting, drying and baling. For cutting a discbine was preferred for the three biomass crops. On co-operator reported that a haybine was able to cut seeded grasses adequately in the early stages of field establishment (first two years); however, as the stand progressed a discbine would be required. Three out of 11 plots directly harvested standing Miscanthus using a forage harvester and commented that this system worked very well.

Figure 4.9- Miscanthus left standing over winter (A), baled (B and C) and stored in field (D)

Drying was only a concern for switchgrass and tall grass prairie plots where the biomass was cut in the fall. To facilitate drying of the windrowed crop, co-operators would increase cutting height from that typically used for cutting hay (2-4 inches) to 4-6 inches. Three of the 22 co-operators who established switchgrass or tallgrass prairie plots and left 4-6 inches of switchgrass stubble expressed some concern regarding the lost reduced yield associated with increased cutting height. Hay rakes were used on five plots (4 establishment year plots and one third year plot) in the spring of 2011 to flip the windrow to further dry the crop. Those that did not rake the windrow commented that a rake is not necessary if sufficient sunlight and wind results in adequate drying conditions.

Large square bales were considered the baling method of choice by co-operators. The balers were reported to have all easily handled the amount of material in the windrows. Only some had problems with slowing down the baler when the mowing swath was too large or several windrows were combined. The main benefit of large square bales is that they are adjustable in length and density to best meet the storage available and adapt to the best size and weight for transporting to the end-user. Baling with a small square or round baler were chosen by some co-operators but this was not the preferred option. Co-operators using this baling method typically owned the equipment so that a custom operator was not required. Round bales of Miscanthus worked well for one co-operator while round bales of switchgrass were not suitable for another co-operator who the net wrapping would rip when bales were handled and moved during transport.

Yield losses during harvesting were reported at eight plots in the 2012 harvest and none in 2011 and 2010 harvest. When harvesting Miscanthus, one co-operator at one plot reported minor yield losses (< 10%) of canes that were broken and fell below the height of the harvester. Seven seeded grass plots at two co-operator locations reported yield losses either from windrows being packed down by snow over winter (< 20% losses) or lodging following seed harvesting. In the case where the co-operator harvested seed from the plots they reported minimal material being left on the ground but from assessments of the plots by OSCIA staff significant lodging occurred where ~ 90% of the biomass was below 6 inches. Some co-operators have questioned the benefit of mowing the grasses in the fall and have expressed interest in leaving them standing over winter. Another concern expressed by several producers, regardless of crop or step in the harvesting process was that stubble can put holes in smaller implement tires. Two co-operators reported having to compensate custom harvesters for damaged tires. Future modifications to existing equipment may include using foam filled implement tires. Nott Farms uses foam filled implement tires to prevent tire damage and reduce equipment down-time when harvesting switchgrass.

Key learning's from co-operators are that standard farm equipment can be used for harvesting purpose-grown biomass crops in all plots across Ontario. Discbines and large square balers are best suited to handle established biomass grass crops. Where available, a high density square baler is recommended for any material that will be transported off the farm. Further investigation of the ability of seeded grass plots to remain standing over winter will need to be looked at by co-operators as a possibility to reduce harvesting losses.

4.12. Storage and transport of harvested material

Baled material was predominantly stored in field, either uncovered or covered with a tarp. A few co-operators were able to store material in unused barns or covered shed space. Where a producer directly harvested using a forage harvester, chipped material was kept in either a pile in covered storage in an Ag-bag using a silage bagger. Beyond storage, the harvested material was transported by flatbed truck, typically using a third party trucking company. In most cases shipping was at the cost of the producer and not the end user.

Material left uncovered has not shown any signs of degradation to date with the bales only taking on moisture on the outside 20-30 cm of exposed bales. Comments from the 4 co-operators that chipped material were that it was very light material, with too low a density for convenient storage or transport. They felt that direct harvesting into a chipped form of material would only be realistic if the producer had large areas for extra storage and would be directly processing (e.g. pelletizing) on site.

Storage of biomass has not been a concern of co-operators, who were able to use existing storage or store bales outside for the small quantities of biomass harvested from the plots during this project. Storage of high density bales is preferred over low density chipped material from a forage harvester as the size of storage required is lower and bales can be left outside with minimal degradation. The distance the biomass will be transported is an important consideration when choosing bale size and density to maximize profitability.

4.13. Biomass Markets and End-Uses

Before the fall of 2012 none of the co-operators involved in this study sold biomass off farm. Any biomass harvested by co-operators prior to 2012 was stored. In the fall of 2012 biomass was sold by co-operators as a high fibre component of cattle feed (switchgrass). In the spring of 2013 biomass was sold by co-operators as mushroom compost mulch (switchgrass), and bedding (Miscanthus, switchgrass, indiangrass). Biomass was sold for 5-7.5 cents per pound in the fall and spring of 2012 and 2013. In addition to biomass that was sold, co-operators provided samples of biomass to potential markets as bedding for cattle and horses (switchgrass), specialty mushroom compost mulch (switchgrass) and nutrient extraction from biomass (switchgrass).

One co-operator has used his harvested tallgrass prairie as mulch and used it on farm for 4.5 ac of strawberries since 2010 (Figure 4.10).

Figure 4.10- Tallgrass prairie used as mulch for strawberries

In 2012 Ontario experienced a dryer than normal growing season that lead to hay and straw shortages across much of the province. The shortages and increased prices for hay and straw allowed co-operators to test several of the biomass crops in markets not previously considered (refer to Appendix C- Co-operator Profiles). The first of these markets was late summer cut switchgrass that was sold as cattle feed by one co-operator in the fall of 2012. This is not likely to be a long term stable market as the co-operator commented that the switchgrass was not a desirable feed for cattle. Switchgrass use as cattle feed will likely only be considered by farmers in years of short straw supply going forward.

Mushroom compost mulch was another potential market pursued by switchgrass producers as a result of high straw prices in 2012. Two switchgrass producers (one co-operator and Nott Farms) sold their biomass as a wheat straw replacement in mushroom compost mulch in the winter and spring of 2012-2013. Feedback received by the biomass producers was that the mushroom producers preferred the switchgrass fibre over wheat straw. The mushroom producer reported that the longer fibre length and greater stem strength allows for more aeration in the mulch, and speeding up of the composting process. More research is needed to substantiate these claims. Additionally, the willingness of mushroom producers to purchase the switchgrass at 5-7.5 cents per pound in the long term needs to be addressed. If switchgrass is preferred mushroom compost, mulch could provide a large stable market for biomass producers in much of Ontario.

Livestock bedding was another market accessed by four co-operators. Livestock bedding presents a market that could be accessed by many producers in all areas of the province. To validate the suitability of biomass grasses for use as livestock bedding four farmers who have tested switchgrass as bedding were contacted for their feedback. The farmers represent a range of livestock operations; two dairy farms, one veal farm and one feeder cattle/finishing pigs farm. Three of the four farmers contacted gave positive feedback that switchgrass is a good replacement for straw while one farmer did not see it as a suitable replacement for his diary cows. Positive feedback from the three farmers included; blends well, absorbency similar or slightly better than wheat straw, source of organic bedding, packs down well, more durable, cow's did not try to eat it and it producers a higher quality manure as it ferments better than wheat straw. While comments from the farmer who did not feel it was a suitable replacement to wheat straw included; really dry, dusty and poor absorbency. Overall, suitability of switchgrass for bedding may vary depending on the requirements of the specific end user. While co-operator opinions were recorded on the use of grasses for these markets detailed studies of absorbency, fibre strength, cutting length, in-field degradation/decomposition, etc. are still needed. Biomass for use as livestock bedding will likely only become a stable market for producers where it is preferred over straw.

Co-operators are also pursuing manufacturing and selling value-added products within their own businesses. Two examples include; composting and directly marketing compost to consumers (Miscanthus) and blending fibres with plastics in injection molding (Miscanthus). In addition to markets that co-operators sold or provided test product for, opportunities for mulch for carrots and ginseng crops, fibre board to replace particle board in manufacturing and construction, use for cellulosic ethanol and biochemicals continue to be pursued by co-operators.

5. Conclusions

The Field-scale Agricultural Biomass Research and Development project has been to support Ontario farmers to obtain on-farm pilot scale field-plot experience with purpose-grown biomass crops. The project aimed to assist farmers in identifying success factors for establishment, production and market development of purpose-grown biomass over 4 growing seasons (2010-2013). By encouraging adaptive research with 28 producer co-operators over 725 ac the project gave farmers opportunities to develop site specific solutions to agronomic and productive capacity challenges with purpose-grown biomass crops. The 56 plots grown by co-operators represented a wide geographic, soil type and land class range in Ontario. Three cropping systems were selected for investigation; Miscanthus, switchgrass and tallgrass prairie. Producer experiences were collected from annual surveys completed by the producers, producer reported yield and harvest moisture and field data collected by OSCIA staff.

Field preparation (including the previous cropping history of the field), weed control, planting date were all observed to be important factors in successful crop establishment and reaching the crops maximum yield potential. Field preparation depended on the crop grown the year prior to planting, however the most common field preparation was no tillage and chemical burndown of weeds with a broad spectrum herbicide in the spring prior to planting into soybean stubble. Producers who established biomass grasses on fields where hay, alfalfa or pasture had previously been grown experienced greater problems with weed control in the establishment years. It should be noted that hay and pasture tends to be associated with soils/fields with lower land capability classes (i.e. “marginal” land) and if production of these grasses is targeted to these soils/fields, then field preparation practices may need to be studied further to determine best management practices to ensure establishment and effective weed control.

Miscanthus and switchgrass varieties selected by co-operators were often varieties that other biomass grass producers have shown successful establishment in Ontario or are varieties recommended by the suppliers used by co-operators in Ontario and Pennsylvania. Tallgrass prairie varieties were all locally collected ecovars. Further research trials are required in Ontario to fully assess the suitability of a range of Miscanthus and switchgrass varieties for their yield potential and winter survival abilities. Planting of seeded grasses was by broadcasting or no-till drilling seed at 7-12 lbs PLS ac^{-1}. Miscanthus rhizomes or plugs were planted using modified transplant planters or other similar equipment locally available and planting 5000-16000 rhizomes ac^{-1} or 4500-16000 plugs ac^{-1}. Optimal planting timing remains a concern to several co-operators. Late planting (beyond mid-June) was thought to have negatively affected grass establishment and presented increased challenges with weed control.

Fertility of the biomass crops was not considered by most co-operators as essential for crop production. Fertilizer was only applied on crops that were in the second year of stand establishment or older to minimize weed pressure on the establishing crop. Fertility management of N, P and K was not based on soil test results by most co-operators but on recommendations from other biomass producers in Ontario. Fertility recommendations still require further development depending on the harvest practices used (fall vs. spring harvesting) and economical rates of N application depending on end use markets.

Several different weed control methods were used by co-operators. Mowing weeds was preferred in the establishment year of seeded grasses. In subsequent years of grass production chemical weed control was preferred. Herbicides previously registered for use in Ontario on other field crops have been identified by co-operators to help weed control in biomass grasses. Annual broadleaf weeds were controlled in most plots while perennial broadleaf weeds and perennial grass weeds were more challenging. Weed pressure in the various plots was a function of the previous cropping history of the field as well as planting timing. Weed control was more likely to be successful in fields with a history of grain crop production and planting occurred in May and early June. Successful weed control in the early years (year 1 and 2) resulted in better stand establishment and yield potential in the long term (3+ years). In a few plots re-establishment of the grasses in the second or third year following initial establishment was attempted where there was late planting and problems with weed control. Re-establishment by overseeding seeded grasses was successful but filling in missing Miscanthus plants or “stitching” was labour and time intensive and the new plantings were not vigorous due to competition.

Miscanthus yields reported by co-operators were in line with those reported in field trials in Ontario. Switchgrass yields were less than half of what has been observed in research trials in Ontario. Co-operators reported yields below anticipated in the second and third year of establishment. Further collection of yields from these plots as they mature is required. It is possible that in many cases in Ontario peak yield potential will not be reached until beyond the third year of establishment, especially on poorer quality soils and climates with shorter growing seasons. The crops were able to be successfully harvested using existing farm equipment such as mowers, balers and forage harvesters. Crops were left over winter either standing (Miscanthus) or mowed and left to dry on the plant stubble (switchgrass and tallgrass prairie). Harvesting the crop in the spring, between April and June allowed for all of the grass species and varieties to be taken off the field at ~10 % moisture. Harvested material was stored on farm either in the field or in covered storage. Co-operators for sold biomass for use in mushroom compost, cattle feed and bedding. Further work is required to continue to develop other high value markets such as blending biomass fibres with plastics in injection molding processes, as a fibre to replace particle board in manufacturing and construction, cellulosic ethanol and biochemicals.

Decisions by co-operators on many aspects of biomass grass production were based on experiences from other producers within Ontario, switchgrass production guides and seed/rhizome supplier recommendations. There are currently two production guides specific to Ontario production conditions for switchgrass and no published documents for Ontario production of Miscanthus or tallgrass prairie are available to producers (Samson, 2007, Switchgreen, 2009). While providing recommendations for production little information is available from these guides and supplier recommendations beyond rough guidelines for details such as variety selection, planting date, fertility, weed control etc. Recommendations for Miscanthus, switchgrass and tallgrass prairie production are required from a range of geographic locations with controlled replicated research trials of multiple varieties of each species, multiple fertility and weed control management strategies and planting date comparisons for a comprehensive production guide for biomass crops in Ontario.

This project gave the opportunity to 28 producer co-operators in Ontario to experiment and pathfind the agronomics of biomass crop production. Many biomass producers in Ontario struggled to develop site specific solutions to agronomic and productive capacity challenges with purpose-grown biomass crops. This can likely be attributed to the slow development of markets and producers lacking time or interest in developing crop experience where the financial payoffs are unknown. While many basic agronomic questions were addressed and biomass productive capacity was developed, more detailed agronomic questions still remain. Agronomic questions of variety selection and suitability for different regions, effective grass weed control and fertility management for optimal economic returns are among some of the questions that still remain. Biomass research should continue in Ontario and efforts should be made by co-operators, agricultural organizations and government to maintain the low maintenance and cost field plots where this project invested in establishment.

6. Appendices

Appendix A- Literature Review of Biomass Cropping Systems Selected for Ontario

1. Miscanthus

The genus *Miscanthus* comprises a group of more than fifteen grass species, most of which are native to eastern Asia, where they were cultivated as an ornamental plant (Brown, 1979). The most researched Miscanthus species in North America and Europe to date is M. x *giganteus,* which is an interspecific hybrid of *M. sinensis* (a diploid species) and *M. sacchariflorus* (tetraploid species). The resulting hybrid is a noninvasive sterile triploid and must be vegetatively propagated. Vegetative propagules include rhizomes with several terminal buds directly planted into the field, stem cuttings directly planted, or transplant plugs generated from rhizomes, micropropagation techniques or stem/rhizome propagules (Atkinson, 2009). Planting of Miscanthus cuttings or plugs in Southern Ontario occurs between early May and mid-June. A stand density of 10,000 plants ha^{-1} is considered optimal to maximize yield (Atkinson, 2009).

The Miscanthus growing season in Ontario is from early spring (April) until frost in November (Kludze et al. 2011). New growth originates from the buds on the rhizomes from previous years. Senescence of late-flowering Miscanthus genotypes is often initiated by frost. During this period the plants may produce a flowering seed head but do not produce viable seed. During senescence a slow yellowing of the tissues occurs followed by the eventual dropping of the leaf material and seed heads, leaving the stems standing. The ability of the plant to undergo a slow senescence may be associated with improved plant stand survival (Heaton et al, 2009).

The cropping period of a Miscanthus stand may exceed twenty years in Europe (McKendry, 2002). However, the stand persistence and life-span is thought to potentially be lower in Ontario where there are different soil and climactic conditions than Europe (Kludze et al., 2011). A Miscanthus stand has two distinct phases, the establishment phase and the main use phase (Kahle et al., 2001). The establishment phase typically occurs between planting and the third and fourth growing season, although some studies have shown it to be longer (Kahle et al., 2001). During the establishment phase, average annual dry matter production increases (Gibson and Barnhart, 2007; Heaton et al., 2004). Yields of Miscanthus are often only reported from stands that are three or more years of age. At this age, stand productivity plateaus and the main use phase is reached.

Yields in the first year of the establishment phase can be expected to be ~30% of that of a fully established stand and ~70% by the second year (Clifton-Brown and Lewandowski, 2002; Heaton et al., 2008). On fertile soils, Miscanthus can reach full yield potential by the third year (Pyter et al., 2009). Full yield potential may not be achieved until the fourth or fifth year on lower quality soils. Miscanthus yields on fertile soils in Ontario can reach up to 30 t ha^{-1}. On shallow, droughty, cold or waterlogged soils, yield may be greatly reduced to below 10 t ha^{-1} (Kludze et al. 2011; Pyter et al. 2009). Yields of Miscanthus in southwest Ontario may be more than double those of upland switchgrass (Samson, 2007).

Miscanthus' ability to grow in cold temperatures and produce high yields can be attributed to its ability to use the C4 photosynthetic pathway. By using this pathway, Miscanthus and some other field crops (such as corn and sugarcane), have a high photosynthetic efficiency. However, unique to Miscanthus is its ability to retain a high level of photosynthetic efficiency at low temperatures (Beale and Long, 1996; Naidu et al., 2003). Miscanthus can be productive later into the growing season than other field crops. At temperatures where photosynthetic rates of corn are decreased, Miscanthus can remain unaffected (Naidu et al., 2003). In addition to Miscanthus' more efficient photosynthetic pathway, it has been shown to have good water use efficiency and a relatively low nutrient requirement (Kludze et al., 2011). As well, by managing harvest timing and delaying harvest from the fall to the spring, nutrient removal can be significantly reduced in some locations in Ontario (Engbers et al., 2012).

2. Switchgrass

Switchgrass is a native perennial C4 grass component of the North American tallgrass prairie. There are two distinct types of switchgrass; upland cultivars and lowland cultivars (Brown, 1979; McLaughlin and Kszos, 2005). Lowland cultivars have the greatest yield potential, but are susceptible to cold injury and are found in wetter habitats, making them not suitable for cultivation in Ontario (Gibson and Barnhart, 2007). Examples of lowland cultivars include Kanlow and Alamo. Upland cultivars are adapted to cool, dry climates such as those experienced in Ontario (Samson, 2007). Examples of upland cultivars include; Shelter, Cave-in-Rock, Blackwell, Pathfinder, Sunburst, Trailblazer and Caddo. Switchgrass can be planted by seed, either broadcast or no-till drilled in Southern Ontario between late April and mid-June. Seeding rates between 8-11 lbs PLS (Pure Live Seed) ha^{-1} are generally recommended (Samson, 2007; Switchgreen, 2009). Some seed sources will have high seed dormancy, especially newly harvested seed. Seeding rates need to be adjusted to include dormant seed and PLS. A percent dormant seed below 10% in newly harvested seed is considered optimal (Kludze, 2011).

In Ontario, active growth of the species occurs during the warm months from June to August. Switchgrass can be relatively slow to establish, with seemingly poor stands during the seeding year (Gibson and Barnhart, 2007). In Ontario trials, Samson (2007) observed that switchgrass establishment is more consistent and rapid on well-drained loam and sandy soils than on clay soils. As a component of the North American tallgrass prairie, switchgrass can grow well on soils that are marginal for row crop agriculture. Like Miscanthus, switchgrass uses the C4 photosynthetic pathway and has a higher photosynthetic efficiency than C3 plants. Additionally, switchgrass varieties have been extensively evaluated and selected since the 1980's to have a high resistance to pests and diseases, water stress conditions and marginal soils, allowing it to be used as a low management crop (McLaughlin and Kszos, 2005; Monti et al., 2008; Parrish and Fike, 2005; Samson, 2007; Vogel and Pedersen, 1993).

Commercially grown switchgrass follows two phases of growth, the establishment phase and the main use phase. Switchgrass establishment can take 1 to 2 years before harvestable yields are obtained and it enters the main use phase. Since switchgrass produces viable seed, it is believed to continue to reseed itself with new plants and therefore the productivity of the stand may be indefinite.

Switchgrass yield potential is generally assessed when the stand has reached its main use phase, is in its second or third year and at maximum yield (Gibson and Barnhart, 2007; Samson, 2007). In a review conducted by Heaton et al, (2004), established switchgrass had an average yield of 10 T DM ha^{-1} (over 77 observations). In side-by-side studies at three Illinois locations, upland switchgrass yields were 50% less than for *Miscanthus giganteus* (Heaton et al., 2004). In Illinois, yields for the unfertilized upland switchgrass variety 'Cave in Rock' seeded in 2002, averaged over the 2004 through 2006 growing seasons were, 4.9 T DM ha^{-1} in Northern Illinois, 11.6 T DM ha^{-1} in Central Illinois, and 6.1 T DM ha^{-1} in Southern Illinois (Heaton et al., 2008). Similar to the results with Miscanthus, switchgrass yield was significantly influenced by location (Fike et al., 2006). In Ontario, established stands can produce 8-12 T DM ha^{-1} under a fall harvest management (Samson, 2007).

3. Mixed Tall Grass Prairie

Tall grass prairies once dominated many Ontario landscapes but have been on the decline since the modern agricultural revolution. Tall grass prairie has disappeared from the Canadian landscape to the extent that now only 1% of the original tallgrass ecosystem in North America remains (Tallgrass Ontario, 2005). As a result, attempts have been made by landowners and stewardship organizations to re-establish tallgrass habitats in Ontario.

Planted tall grass prairie is a mix of native warm season grasses and non-grassy herbaceous wildflowers that were formerly widespread throughout Ontario. Seed mixtures are often planted by a seed drill between late April and mid-June. Mixtures can vary greatly from two grass species to a few dozen grass species and wildflowers. Five species of grasses comprise approximately 95% of the grass biomass at any given site (Tallgrass Ontario, 2005). The 5 species are; big bluestem (*Andropogon* gerardii), indiangrass (*Sorghastrum* nutans), little bluestem (*Schizachyrium* scoparium), prairie cordgrass (*Spartina* pectinata) and switchgrass. Over 30 other grass species can comprise the other 5% of the mixture. In addition to grasses, prairie mixtures often contain prairie wildflowers, known by the collective name of "forbs". These forbs are often added to the mixture to attract wildlife and pollinating insects, but also may include some nitrogen fixing species (Tallgrass Ontario, 2005).

Prior to human intervention tallgrass prairie relied on fire for prairie management. Fire was beneficial for these ecosystems for several reasons (Tallgrass Ontario, 2005);

- A way to kill plants not specifically adapted to tolerate fire (eg; trees and shrubs)
- Dead standing material was eliminated to allow for more sunlight and wind to warm and dry the soil surface (speeding up development of underground shoots)

- By eliminating dead standing material more moisture was able to reach the soil surface and be available to plants

Restored tall grass prairie sites often still reap the benefits of fire through the use of prescribed burns where a fire is deliberately set and controlled by an experienced team of burn technicians (Tallgrass Ontario, 2005). In some cases, fields are burnt as much as every year, which is a costly procedure. Therefore, while some native tall grass prairie fields were not planted with the intention of the removal of biomass, it may be able to provide a source of biomass and revenue to landowners. If biomass is removed, the prairie would be burned every several years or limited to burning the stubble.

Appendix B- Survey Information Collected

1. **Contact Information**

a. Name:

b. Phone:

c. E-mail:

2. **Site Information**

a. What is the dominant soil type of the biomass acreage?

b. What is your soil capability for agriculture?

c. Approximate estimation of % sand/silt/clay?

d. Soil fertility (N, P, K, pH, please attach last soil test of the applicable plot):

Soil test attatched? Yes or N

e. Variability of the property (topography, drainage, slope, stoniness, windbreaks, etc.)

f. Enclose either an aerial image from a source such as Google earth/satellite with the plot marked out or a rough drawing of the plots in relation to each other and the property.

Image enclosed? Yes or No

3. **Growing Season Weather**

a. Seasonal Accumulated CHU (This can be found in previous copies of the Ontario Farmer or from your local co-op

    a. Source:

b. Rainfall (starting with the month of planting)

May: mm

June: mm

July: mm

August: mm

September: mm

October: mm

November: mm

    a. Source:

4. **The following information is required for each crop or field, depending on how your plots are arranged. If the same plot has multiple crops on it please fill in the survey based on**

crop, if there are multiple plots of the same crop that are separated by a significant distance or variability (e.g. slope, drainage, etc) please fill out based on the plot.

Crop/Field #1-4 (or as many as required)

a. Approximate number of acres
b. Approximate dimensions of plot ft x ft
c. Species
d. Species variety
e. Description of field: (describe in relation to farmhouse, laneway or known access point, please provide as much detail as possible)
f. Variability (in establishment, heights of plants across field, with nutrient application splits or other treatments, etc)
g. Possible causes for this variability? Other comments?
h. Field Preparation (Please provide any feedback possible on the success or lack thereof of the previous crop or operation such as; how hard was it to eliminate, were there volunteer plants, etc? Did the tillage work? Did you notice a difference in efficacy with moisture, depth? What would you have done differently?)
    a. Previous crop: (2 previous calendar years)

	Dates of operation	**Description (type, rate, cost est. etc.)**	**Comments**
Tillage Operation 1			
Tillage Operation 2			
Tillage Operation 3			
Burndown Herbicides			
Other			

i. Planting (Provide the same level of detail as above)
    a. Material Planted
    b. Seeding Rate/ Planting Density
    c. Comment on the quality of the material planted. How long has it been in storage? What was the method of storage and transportation and the conditions?

	Dates of operation	Description (type, rate, cost est. etc.)	Comments
Planting			
Fertilization (during or right after planting)			
Other			

j. **Crop Management** (Provide the same level of detail as above)

	Dates of operation	Description (type, rate, cost est. etc.)	Comments
Stand Re-establishment(if necessary)			
Weed Control			
Fertility(during growing season)			
Other			

k. **Harvest** (Provide the same level of detail as above, if operation has already taken place this year indicate date, if not then indicate approximate timing and proposed method of operation)

	Dates of operation	Description (type, rate, cost est. etc.)	Comments
Swathing/Mowing			
Raking			
Bailing or Forage Harvester			
Transport to Storage			
Storage			
Other			

Appendix C- Co-operator Profiles

i. Scott Abercrombie

Scott owns and operates Gildale Farms, a hardwood pellet company that produces residential, commercial and greenhouse heating pellets. Scott also farms 250 ac of cash crops near St. Mary's, ON. He has had an interest in biomass grasses since 2009, when he imported Miscanthus root stock from Austria. In 2009 he planted 2 ac of the imported rhizomes. Since 2009, he has expanded to 16.5 acres of Miscanthus in 2010 and 2011 using the original 2009 plantings as rootstock. In 2011, 8 acres of Cave-in-Rock switchgrass (purchased from Nott Farms) were also planted to allow a direct comparison of establishment and production requirements and yield potential. The 8 acres of switchgrass was sown into winter wheat in the spring, the winter wheat and straw was harvested in August and the switchgrass left to grow. Sowing switchgrass into the winter wheat was done to provide a source of income in the initial year of planting. Scott was originally interested in pelletizing biomass, in particular Miscanthus, into home and commercial heating pellets. Miscanthus pellets have been produced but with few markets for biomass pellets he continues to produce hardwood pellets.

ii. Tallgrass Ontario (Kyle Breault)

Kyle is the former Program Coordinator for Tallgrass Ontario based out of Ridgetown, ON. Tallgrass Ontario was established in 1999 to recover tallgrass prairie ecosystems in Southern Ontario. The organization as has worked with local landowners to plant different tall grass prairie and forb mixtures across Southern Ontario. The plots are on land owned by the Lower Thames Valley Conservation Authority. The land had been rented by a local farmer for growing corn, soybeans and wheat until 2012. In 2012 the conservation authority agreed to rent the land to Tallgrass Ontario. The objective was to assess if the land could be restored to a native tallgrass prairie system and provide at least enough revenue to cover the cost of renting the land. In 2012 three plots were planted side-by-side; 15 ac of big bluestem, 20 ac of a native grass mixture and 15 ac of a polyculture mixed prairie.

iii. Roy Buchanan

Roy farms 350 ac of cash crops near Thamesville, ON. Roy planted three 8 ac plots side-by-side to allow for a comparison establishment and yield potential of locally sourced native switchgrass, mixed switchgrass and indiangrass and a native tall grass mixture in 2011. Roy first planted 5 acres of native tallgrass prairie and warm season grasses in 2002 but did not harvest or market the biomass.

iv. Canada's Outdoor Farm Show (COFS)

The field at Canada's Outdoor Farm Show is a demonstration plot of four different one acre blocks, two Miscanthus varieties and two switchgrass varieties. The two Miscanthus varieties were planted by program co-operators John Malecki and Scott Abercrombie. Varieties planted were a clone imported from Austria and a Nagara clone provided by New Energy Farms, Leamington, ON. The switchgrass plots were planted and managed by John Malecki. Varieties planted were Cave-in-Rock from Nott Farms, Clinton, ON, and Kanlow from Ernst Seeds of Meadville, PA.

v. Ron and Adam DeVisser

Ron and his son Adam are turkey farmers who farm over 450 acres near Chesley and Elmwood, ON. In 2010 the DeVisser's became interested in planting switchgrass on a field that has steep slopes, is easily erodible and not suitable for cash crop production. The field had previously been pasture but in 2010, 10 ac of Cave-in-Rock switchgrass (Nott Farms) was planted. Five more acres of Cave-in-Rock switchgrass were planted in 2011 on the highly sloped erodible field. The DeVissers planned to fertilize using their own turkey manure and use the harvested biomass as bedding for their turkeys.

vi. John Dumanski

John formerly grew tobacco on his 300 ac farm in Simcoe, ON. He has since diversified to produce grains, vegetables and strawberries. In 2009, John planted 9 acres of a native tallgrass prairie mixture on his farm. The tallgrass mixture was originally planted with the intention of supplying biomass to Ontario Power Generation (OPG) but John has found a use for the harvested material on farm. By using the tallgrass as a mulch for his 4.5 ac of strawberries grown annually, fluctuating straw prices no longer impact the profitability of his strawberries.

vii. Urs Eggimann

Urs farms 310 acres in Holland Center, ON. Much of Urs' workable land has been abandoned pasture and hay fields for over 10 years. The fields have marginal soil quality with shallow topsoil and problems with stoniness. He planted his first two switchgrass fields (11 ac total) in 2009. These two fields had poor establishment and weeds overtook the switchgrass the next year. In 2010, Urs planted another 26.5 acres with greatly improved success. Two plots are all Cave-in-Rock switchgrass (Nott Farms), one field has two switchgrass varieties (Cave-in-Rock from Nott Farms and Sunburst from Ernst Seeds) and one with Cave-in-Rock switchgrass and Prairie View big bluestem (Ernst Seeds). Urs attributes much of the success of the plots planted in 2010 to the use of a broad spectrum herbicide and mowing weeds through the 2009 growing season. Urs' experience with these 2010 plantings has demonstrated that when establishing switchgrass on fields where hay or pasture is being removed, extra field preparation and weed control is necessary.

In 2011, Urs entered the fields planted in 2009 into the program and attempted to re-establish switchgrass. Urs used the plots to compare methods of field re-establishment. One plot was ploughed and replanted while the other was left undisturbed and overseeded. The original planting and overseeding was with Cave-in-Rock switchgrass (Nott Farms) and the replanting a Tecumseh II variety from Roger Samson, REAP Canada, Ste-Anne-de-Bellevue, QC.

Urs has demonstrated that biomass grasses can successfully establish on marginal quality abandoned land. He originally intended to sell biomass as livestock bedding locally and eventually expanded into selling his biomass to mushroom growers via a wheat straw broker.

viii. Hugh Fraser and Chris Pieper

Chris Pieper owns and operates Pieper Nurseries in Dorchester, ON. Chris and Hugh Fraser (Agricultural Engineer, OMAF and MRA, Vineland Research Station) established this trial in 2008 as a part of the Great Lakes Program. The trial was designed to test the benefits of using a vegetated filter strip of Miscanthus to remove nutrients from recycled irrigation water. Two Miscanthus varieties were planted from plugs; Nagara and T-select from New Energy Farms, Leamington, ON. There are 12 plots (6 of each variety) each 10 m by 10 m where half of each variety is irrigated as needed throughout the summer and the others receive no irrigation. They have been able to continue this trial since 2011 under this program, irrigating and harvesting annually.

ix. Louis Gaal

Louis farms 60 acres in Winchester ON. He attempted to establish 30 ac of switchgrass on a old pasture field in 2012. Seed was purchased from Hendricks Seeds, Inkerman, ON. Two different seeding densities of switchgrass were used; a density recommended by Hendricks and a double density. The switchgrass seed was broadcast with oats. The oats were meant to be a cover crop to control the weed pressure on this organic farm. Louis plans on selling bailed material to Switchgreen, Kingston, ON.

x. Ted Hayes

Ted owns and operates a 1780 acre cash crop operation in Lions Head, ON. He planted 8 acres of Miscanthus near Wiarton, ON in 2011. The 8 acres are a Nagara variety from New Energy Farms, Leamington, ON. The Miscanthus was planted as plugs or rhizomes and each at two different densities.

xi. Bob Hunter

Bob Hunter owns and operates 6000+ acre cash crop operation around Prince Edward County. Bob has worked with hemp and specialty crop experts for several years. In 2010, he expanded into herbaceous biomass crops by planting 19 acres of Miscanthus. Bob planned to expand from 19 ac to 600 acres over 2 years. The 19 acres of Miscanthus in Osaca, ON, were planted by plugs and rhizomes over a two week period into a field with a history of low grain crop yields. The Miscanthus is a Nagara variety from New Energy Farms, Leamington, ON. Bob experimented with several methods of weed control in Miscanthus, including using mushroom compost for weed control and fertility. Bob had plans to operate his own pellet mill and sell biomass pellets for combustion.

xii. Jon Lechowicz

Jon farms 125 acres of tobacco and vegetables in Burford, ON. Jon first experimented with biomass crops in 2009 when he planted Miscanthus, switchgrass and empress trees on his farm. Only 1.5 ac of switchgrass successfully established and was harvested for the first time when he joined this project in 2011. The switchgrass was the Cave-in-Rock variety from Nott Farms. Jon planned on selling the switchgrass as livestock bedding to local dairy farms.

xiii. Rural Lambton Stewardship Network (RLSN)

The RLSN is an organization dedicated to habitat restoration and conservation. RLSN is interested in the potential tallgrass prairie species could play in retiring low quality cash crop acreage into biomass filter strips or as a long term rotational crop to improve soil quality. RLSN harvests, cleans, sells and custom plants their own prairie grass mixtures. RLSN also conducts prescribed burns on their prairie sites.

RLSN has two biomass project sites. The first site is an existing seed propagation field north of Bothwell, ON, where local ecovars of big bluestem (17 ac), Indiangrass (2 ac) and switchgrass (28 ac) were planted in 2007. The field was harvested for seed and burnt using prescribed burn techniques between 2007 and 2011. This field has the potential for biomass to be removed and the field only burnt every 5 years. They intended to sell the biomass to be pelletized locally.

The second project co-ordinated by RLSN is at a new plot site near Courtright, ON. This plot of 40 ac is owned by a large greenhouse operation interested in irrigating a biomass crop with nutrient rich waste water. RLSN planted their own seed mixtures in 10 ac parcels of switchgrass, polyculture grasses, polyculture grasses with forbs and prairie cordgrass in 2011. This project was removed from the program in the fall of 2012 when the greenhouse operation decided to expand their facility onto this land.

xiv. John Malecki

John Malecki share crops his farm near Drumbo, ON. and has been involved with several sectors of renewable energy in the past decade. John's experience with purpose-grown biomass crops began in 2008, when he planted 0.5 ac of *Miscanthus x giganteus* rhizomes imported from the United States. In 2009 John planted 3 ac of *Miscanthus x giganteus* rhizomes imported from Austria, the same clone as Scott Abercrombie. In 2010 John planted another 3 ac of Nagara variety rhizomes from New Energy Farms, Leamington, ON. Under this program, in 2011 John planted 13 ac of the Nagara variety rhizomes. Rhizomes either came from New Energy Farms or were harvested from his 2010 3 ac field of the same variety. John choose the 13 ac field for converting from a cash crop rotation to Miscanthus because it is adjacent to an environmentally sensitive wet land and spring fed ponds. In addition John planted 6 ac of Cave-in-Rock (Nott Farms) in 2011 in a nearby field. John originally had planned to pelletize his biomass for on-farm heating.

xv. Jim McComb

Jim farms 400 acres and raises beef cattle near Stirling, ON. He planned on planting 10 ac of Miscanthus but was only able to plant 0.8 ac of Miscanthus in July of 2011. The Nagara variety Miscanthus was planted from plugs but likely as a result of late planting there was extensive winterkill and he was not able to evaluate the range of weed control and fertility options originally planned. Jim is also a crop consultant for Bob Hunter and planned to sell his biomass to Bob for pelletizing for combustion.

xvi. Greg and Mira Melien

The Melien's farm 160 acres in Warren, ON. Greg and Mira grow market vegetables and Haskap berries for their winery. They planted 11 ac of switchgrass seed purchased from Ernst Seeds in 2012. Cave-in-Rock and Forestburg varieties were planted at two different densities (8 and 12 lbs ac^{-1}). They are in the process of becoming an organic farm and Ernst Seeds was able to provide the certification they required. They intended to pelletize the biomass on site and burn for heating the winery.

xvii. Peter Peeters

Peter farms 230 acres and beef cattle in Omemee, ON. Peter planted 5 ac of Miscanthus and 10.5 ac of switchgrass in 2011. The Nagara Miscanthus was planted late in the end of July 2011 both as plug and rhizomes (New Energy Farms). There were two varieties of switchgrass planted next to the Miscanthus in 2011, Cave-in-Rock and Forestburg from Hendricks Seeds, Inkerman, ON. In the field Peter replicated strips of switchgrass varieties and experimented with added fertility (vs. no fertility) and mowing weeds (vs. left unmowed). The field chosen previously had a history of low yields for cereal crops and has multiple springs that keep the soil saturated through most of the growing season causing problems with planting and harvesting. Peter intended to sell bailed material to Switchgreen, Kingston, ON, for pelletizing and combustion markets.

xviii. Eleanor Renaud

Eleanor farms over 1000 acres and raises beef cattle in Jasper, ON. Eleanor chose to plant switchgrass on 5 smaller plots (8.5 ac spread out) that were inconvenient for cutting hay or pasturing. The Cave-in-Rock variety of switchgrass was purchased from Nott Farms and planted in 2011. Eleanor planed on using the switchgrass as bedding for the cattle.

xix. Mark Schwartz (Greenfield Ethanol)

Greenfields owns land in Hensall, ON beside the Hensall District Cooperative. The land was purchased with the intention of building an ethanol plant but was cancelled. Some land preparation had begun and there are sections of the field where topsoil has been removed. They decided to plant one acre of Miscanthus and 16 acres of switchgrass in collaboration with a local farmer (Wayne Campbell, Hensall, ON). The Miscanthus was the Nagara variety (New Energy Farms), planted as plugs in 2011. The switchgrass seed was obtained from Ceres from Thousand Oaks, CA and planted in 2011. Three varieties of switchgrass were chosen; Blade Blackwell, Blade EG1102 and Blade EG2101. However, no records of where each species were planted were able to be obtained by Mark or Wayne. The biomass from these plots was to be used as test feedstock at Greenfields cellulosic ethanol test facility.

xx. Marvin Smith

Marvin farms 460 acres in the Rainy River area, in Devlin, ON. Before joining this program Marvin planted 5 acres of switchgrass, reed canary grass, big bluestem and Miscanthus between 2009 and 2010. He experienced almost complete winterkill of all species except Miscanthus during those years. As a result Marvin chose to expand his Miscanthus plantings to 13.5 acres in 2011. The Nagara variety (New Energy Farms) was planted from plugs from mid-June to mid-July. Marvin intended to sell harvested biomass to Abitibi-Bowater Generation’s pulp and paper mill in Thunder Bay for power generation.

xxi. Barry Thompson

Barry farms 700 acres of cash crops in Kemptville, ON. He planted 29 acres of Cave-in-Rock switchgrass (Hendricks Seeds) in 2010 prior to joining this program in 2012. Barry intended to sell bailed material to Switchgreen, Kingston, ON, for pelletizing and combustion markets.

xxii. Dean Tiessen

Dean is the president of New Energy Farms in Leamington, ON. They are the only distributor of Miscanthus genetics in Canada. He has worked with Miscanthus since 2007 and has extensive knowledge of the agronomics, genetics, sales and marketing of Miscanthus. Dean joined this program by in 2011 when he planted three different Miscanthus varieties; *Miscanthus* x *giganteus* Illinois clone, *Miscanthus* x *giganteus* M1 European clone and M116, a Nagara variety. Dean has developed specialized rhizome lifting and planting equipment for ease of Miscanthus planting. Dean originally became interested in biomass for its potential to decrease greenhouse growers dependence on fluctuating natural gas prices, a significant expense in the industry. He has continued to develop this concept of pelletizing and heating but also expanded his market interests to bioproducts and bioplastics.

xxiii. Ryan Tiessen

Ryan is a greenhouse grower in Leamington. Ryan is Dean Tiessen's cousin and a business partner with new Energy Farms. Ryan has been growing Nagara, M1 and M1 Select varieties of Miscanthus in 12 ac since 2008. He joined this program by planting 72 ac of Nagara and M1 Miscanthus rhizomes in 2011. Ryan intended to pelletize the Miscanthus for combustion uses in the greenhouse industry as well as potentially sell some for animal bedding.

xxiv. Steve Timmermans

Steve is an avian biologist previously with Bird Studies Canada from Sparta, ON. Steve owns a farm in Dutton, ON, that borders a riparian stream valley and areas of highly erodable fine textured silty clay-loam. Steve chose to remove the field from cash crop production and plant Cave-in-Rock switchgrass (Nott Farms) on a 44 ac field as a part of this program in 2011. Steve intended to sell his switchgrass to Nott Farms for potential use in bioplastics.

xxv. Kurt Vanclief

Kurt operates a sod farm in Ameliasburg, ON where he has grown 64 ac switchgrass since 2006. Through this program he was able to establish another 11 ac switchgrass plot and 1 ac of Miscanthus in 2009 and 2010. The original Cave-in-Rock switchgrass planted in 2006 was obtained from Ernst Seeds of Meadville, PA. Seed collected from the 64 ac was collected and used to plant the 2009 11 ac switchgrass field. The Nagara Miscanthus was planted as plugs obtained from New Energy Farms, Leamington, ON. Kurt has also worked with Scott Banks, OMAF and MRA, on nitrogen fertility trials on switchgrass from 2009 to 2011. Kurt intended to use the biomass in his own pelletizer and market pellets for combustion locally.

xxvi. Remi Van De Slyke

Remi joined this program in 2011 with 19 ac of native mixed tallgrass prairie established in 2010. The property was a sandy soil where alfalfa had previously been grown. In the spring of 2012 Remi withdrew from the program due to unsatisfactory grass establishment. Problems with establishment were likely a result of poor quality seed obtained from a local tallgrass prairie restoration specialist. Remi owns a pellet mill, mainly used for hopps, where he planned on pelletizing the prairie grass. If markets for the pelletized product did not establish, he also had planned on using the grass as a mulch for his ginseng.

xxvii. Doug Young (Dave Baute)

This project was a joint project between Doug Young, Ridgetown Campus, University of Guelph and Dave Baute, Maizex Seeds President and cash crop farmer. This 55 ac plot established in Ridgetown, ON, in 2011, was a replicated field trial of three varieties of Miscanthus (Nagara, M1 and an Illinois giganteus), two varieties of switchgrass (Cave-in-Rock and Carthage) and a native tallgrass prairie mixture. In the fall of 2012 Doug withdrew this plot from the program due to unsatisfactory grass establishment. All grasses were planted late, with seeded grasses (switchgrass and prairie) in late June and Miscanthus in mid July and this likely contributed to the poor establishment.

Appendix D - Crop Planting and Field Preparation

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation: Mechanical	Field Preparation: Chemical Burn down (Yes or No)	Species	Variety	Planting Date(s)	Planting Density	Planting method
Abercrombie	Silt loam	1	Soybeans	Fall ploughed, spring cultivated, spring rototilled (all 4-5 inches)	N	Miscanthus	Austrian giganteus	25-April-09 and 6-May-09	5000 rhizomes/ac	Modified transplant planter (4 row)
Abercrombie	Silt loam	1	Corn	Fall ploughed, spring cultivated, spring rototilled (all 4-5 inches)	N	Miscanthus	Austrian giganteus	30-April-10, 5-May-10 and 27 and 28-May-10	5000 rhizomes/ac	Modified transplant planter (1 row)
Abercrombie	Silt loam	1	Soybeans	Fall ploughed, spring cultivated, spring rototilled (all 4-5 inches)	N	Miscanthus	Austrian giganteus	12-May-11 to 13-May-11, 3-Jun-11 to 4-Jun-11, 17-Jun-11, 21-Jun-11	5000 rhizomes/ac	Modified transplant planter (1 row and 4 row)
Abercrombie	Silt loam	1	Soybeans	Grass broadcast into winter wheat	Y	Switchgrass	Cave-in-Rock	21-May-11	10 lbs/ac	Broadcast seeded
Breault	Sandy loam	2	Corn	None	N	Tall grass prarie mixture with	Native ecovars	14-May-12	8 lbs/ac	No-till grass drilled

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
						forbs				
Breault	Sandy loam	2	Corn	None	N	Big bluestem	Native ecovars	14-May-12	8 lbs/ac	No-till grass drilled
Breault	Sandy loam	2	Corn	None	N	Switchgrass/ Big Bluestem/In diangrass	Native ecovars	14-May-12	8 lbs/ac	No-till grass drilled
Buchanan	Loamy sand	2	Soybeans	None	Y	Switchgrass	Native ecovars	10-Jun-11	9.6 lbs/ac	No-till grass drilled
Buchanan	Loamy sand	2	Soybeans	None	Y	Switchgrass/ Indiangrass	Native ecovars	10-Jun-11	9.6 lbs/ac	No-till grass drilled
Buchanan	Loamy sand	2	Soybeans	None	Y	Tall grass prairie mixture with forbs	Native ecovars	10-Jun-11	8 lbs/ac	No-till grass drilled
COFS	Silt loam	1	Soybeans	Disked and packed just prior to planting	Y	Miscanthus	Nagara	6-Jun-11	10000 rhizomes/ ac	Modified transplant planter (4 row)
COFS	Silt loam	1	Soybeans	Disked and packed just prior to planting	Y	Miscanthus	Austrian giganteus	6-Jun-11	10000 rhizomes/ ac	Modified transplant planter (4 row)
COFS	Silt	1	Soybeans	Disked and	Y	Switchgrass	Cave-in-	10-Jun-11	9 lbs/ac	Broadcast

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
	loam			packed just prior to planting			Rock			seeded
COFS	Silt loam	1	Soybeans	Disked and packed just prior to planting	Y	Switchgrass	Kanlow	10-Jun-11	9 lbs/ac	Broadcast seeded
DeVisser	Clay loam	3	Pasture	None	Y	Switchgrass	Cave-in-Rock	17-May-10	9 lbs/ac	No-till drilled
DeVisser	Clay loam	3	Pasture	None	Y	Switchgrass	Cave-in-Rock	1-Jun-11	10 lbs/ac	No-till drilled
Dumanski	Sandy Loam	2	Soybeans	Planted into soybean stubble	Y	Tall grass prairie mixture	Native ecovars of Big Bluestem, Indiangrass and Switchgrass	1-Jun-09	4.5 lbs/ac	No-till drilled
Eggimann	Loam	4	Abandoned Pasture (chemical burndown and mowing	Fall disked, disked twice in the spring (May), packed before and after planting	Y	Switchgrass	Cave-in-Rock and Sunburst	17-May-10	12 lbs/ac	Broadcast seeded

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
			in 2009)							
Eggimann	Loam	4	Abandoned Pasture (chemical burndown and mowing in 2009)	Fall disked, disked twice in the spring (May), packed before and after planting. Seed broadcast.	Y	Big Bluestem	Prairie View	21-May-10	20 lbs/ac	Broadcast seeded
Eggimann	Clay loam	4	Abandoned Pasture	Overseeded in 2011, disked 3 times in spring 2009	N	Switchgrass	Cave-in-Rock	Original planting May-09, overseeded 25-May-11	9 lbs/ac	Broadcast seeded
Eggimann	Clay loam	4	Abandoned Pasture	None	Y	Switchgrass	Tecumseh II	15-Jun-11	12 lbs/ac	Broadcast seeded
Fraser	Sandy loam	1	**	**	**	Miscanthus	Nagara	29-May-08	4500 plugs/ac	Hand planted
Fraser	Sandy loam	1	**	**	**	Miscanthus	T-select	29-May-08	4500 plugs/ac	Hand planted
Gaal	Sandy	2	Pasture	Plowed and cultivated two	Y	Switchgrass	Cave-in-	17-Jul-12	8 lbs/ac and 16	Broadcast

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
	loam			years prior to planting, planted with oats			Rock		lbs/ac	seeded
Hayes	Clay loam and Sandy loam	2	Canola	May plowed and disked, June harrowed	Y	Miscanthus	Nagara	1-Jul-11 to 14-Jul-11	5000 plugs/ac, 8000 plugs/ac, 8000 rhizomes/ ac, 16000 plugs/ac and 16000 rhizomes/ ac	Modified transplant planter (1 row)
Hunter	Sand	4	Soybeans	Wheat cover crop removed, disked and cultivated (July)	Y	Miscanthus	Nagara	26-Jun-10 to 12-Jul-10	16000 rhizomes/ ac, 11200 plugs/ac	Modified transplant planter (2 row)
Lechowicz	Sandy loam	1	Rye	Disked twice in early May, cultivated prior to planting	Y	Switchgrass	Cave-in-Rock	23-May-09	10 lbs/ac	Broadcast seeded
Malecki	Loam	3	Soybeans	Heavy disking, tilled and	N	Miscanthus	Nagara	11-May-11 to 12-May-11	5000 rhizomes/	Modified transplant

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
				packed					ac	planter (4 row)
Malecki	Loam	3	Corn	Cut corn stalks prior to disking, heavy disking twice and packed	Y	Switchgrass	Cave-in-Rock	4-Jun-11	9 lbs/ac	Broadcast seeded
McComb	Loam	1	Alfalfa	Summer disked and cultivated (July)	Y	Miscanthus	Nagara	12-Jul-10	14000 rhizomes/ac, 10000 plugs/ac	Modified transplant planter (2 row)
Melien	Silt loam	3	Canola	Fall cultivated three times, spring cultivated	N	Switchgrass	Cave-in-Rock and Forestburg	Spring 2012	8 lbs/ac and 12 lbs/ac	Broadcast seeded
Peeters	Loam	2	Barley	May disked five times, July prior to planting harrowed	Y	Miscanthus	Nagara	26-Jul-11 to 31-Jul-11	12000 rhizomes/ac and 12000 plugs/ac	Tree plug planter (1 row)
Peeters	Loam	2	Barley	May disked five times, July prior to planting harrowed	Y	Switchgrass	Cave-in-Rock and Forestburg	2-Aug-11	**	Broadcast seeded
Renaud	Loam	4	Hay	None	Y	Switchgrass	Cave-in-	27-Jun-11	10 lbs/ac	No-till drilled

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
							Rock			
Renaud	Loam	4	Hay	None	Y	Switchgrass	Cave-in-Rock	16-Jun-11	10 lbs/ac	Broadcast seeded
RLSN (Bothwell)	Sand	2	Soybeans	Planted into soybean stubble	Y	Big Bluestem	Native ecovars	2-Apr-04	8 lbs/ac	No-till grass drilled
RLSN (Bothwell)	Sand	2	Soybeans	Planted into soybean stubble	Y	Indiangrass	Native ecovars	2-Apr-04	8 lbs/ac	No-till grass drilled
RLSN (Bothwell)	Sand	2	Soybeans	Planted into soybean stubble	Y	Switchgrass	Native ecovars	2-Apr-04	8 lbs/ac	No-till grass drilled
RLSN (Courtright)	Clay	3	Corn	None	Y	Prairie cordgrass	Minnesota native ecovars	13-Jun-11	12 lbs/ac	No-till grass drilled
RLSN (Courtright)	Clay	3	Corn	None	Y	Switchgrass	Native ecovars	13-Jun-11	8 lbs/ac	No-till grass drilled
RLSN (Courtright)	Clay	3	Corn	None	Y	Tall grass prarie mixture with forbs	Native ecovars	13-Jun-11	8 lbs/ac	No-till grass drilled
RLSN (Courtright)	Clay	3	Corn	None	Y	Tall grass prairie mixture	Native ecovars	13-Jun-11	8 lbs/ac	No-till grass drilled

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
Schwartz	Clay loam	2	Wheat	**	Y	Switchgrass	Blade Blackwell and EG1102/2101	15-Jun-11*	**	**
Schwartz	Clay loam	2	Wheat	**	Y	Miscanthus	Nagara	15-Jul-11*	**	Hand planted
Smith	Sandy loam	3	Hay (left fallow in 2010)	April ploughed and disked, May disked twice and rolled	Y	Miscanthus	Nagara	19-Jun-11 to 30-Jun-11 and 3-Jul-11 to 15-Jul-11	6000 plugs/ac, 10500 plugs/ac	Hand planted
Thompson	Sandy loam	4	Soybeans	Fall cultivated, rolled before planting	Y	Switchgrass	Cave-in-Rock	1-May-10	10 lbs/ac	Broadcast seeded
Tiessen,D	Clay loam (Clay)	3	Fallow (wheat in 2009)	Disc soil saver	Y	Miscanthus	Nagara, M1 and an Illinois giganteus	22-May-11 to 24-May-11	8000 rhizomes/ac	Specialized Miscanthus planter (4 row)
Tiessen, R	Clay	3	Soybeans	Spring disked (2 inches)	Y	Miscanthus	Nagara and M1	20-Jun-11	6000 rhizomes/ac	Specialized Miscanthus planter (4 row)
Timmermans	Clay loam	2	Soybeans	None	Y	Switchgrass	Cave-in-Rock	9-Jun-11 to 10-Jun-11	9 lbs/ac	No-till grass drilled

Co-operator (last name)	Soil Type	Land Class	Previous Crop	Field Preparation		Species	Variety	Planting Date(s)	Planting Density	Planting method
				Mechanical	Chemical Burn down (Yes or No)					
Vanclief	Clay loam	1	Soybeans	Cultivated deep (10 inches)	Y	Miscanthus	Nagara	15-May-10 to16-May-10	7300 plugs/ac	Modified transplant planter (1 row)
Vanclief	Clay loam	1	Barley	Barley cover crop	Y	Switchgrass	Cave-in-Rock	May-09	7 lbs/ac	No-till drilled
Vanclief	Clay loam	1	Soybeans	**	Y	Switchgrass	Cave-in-Rock	May-06	7 lbs/ac	No-till drilled
Van De Slyke	Sand	2	Corn (organic)	Light disk prior to planting	Y	Tall grass prairie mixture	Native ecovars	15-18-May-10	5.5 lbs/ac	No-till drilled
Young	Clay loam	3	Wheat	RTS mid-June, disked prior to planting	Y	Miscanthus	Nagara, M1 and an Illinois giganteus	12-18-Jul-11	5000 plugs/ac	Modified transplant planter (4 row)
Young	Clay loam	3	Wheat	RTS mid-June, disked prior to planting	Y	Switchgrass	Carthage and Cave-in-Rock	21-Jun-11	8 lbs/ac	No-till drilled
Young	Clay loam	3	Wheat	RTS mid-June, disked prior to planting	Y	Tall grass prairie mixture	Native ecovars	29-Jun-11	8 lbs/ac	No-till grass drilled

*= approximate dates

**= missing information

Appendix E- Letter of Support Submitted for Minor-use Registration of Evaluated Herbicides in Ontario

RE: Letter of support for the minor use registration of broadleaf weed control products on the biomass crops, switchgrass and Miscanthus

February 7, 2012

Dear Sir/Madam,

In 2011, Ontario Soil and Crop Improvement Association (OSCIA) began its Field-scale Agricultural Biomass Research and Development Project. This is a 4-year component of a comprehensive research project funded through the Agricultural Adaptation Council and administered by OSCIA and the Ontario Federation of Agriculture (OFA). The project is designed to determine if purpose-grown agricultural biomass is economically sustainable and an environmentally preferable alternative to coal and non-renewable fuels.

The OSCIA Field-scale Agricultural Biomass Research and Development Project currently includes 26 Ontario producers of purpose grown grass biomass. This project alone represents approximately 750 ac of dedicated grass land, on varying land classes for agriculture. The main crops are switchgrass and Miscanthus. Switchgrass is a native, fertile, seeded, C4 perennial grass that can be grown for several decades with little to no management or weed control beyond the initial year of planting. Miscanthus is a non-native C4 perennial grass originally from Asia that can out yield switchgrass. It is a sterile triploid that must be propagated by rhizome and thus has little potential for invasiveness. Miscanthus can be grown for several decades with little to no management or weed control beyond the initial year of planting. Markets for these crops in Ontario include; combustion for heat or combined heat and power, bio plastics, mulches for crops such as strawberries and ginseng and as animal bedding, primarily for horses and chickens.

Currently these producers have no options for weed control. Various agronomic practices have been used to minimize weed pressure (e.g.; planting after a round-up ready crop, multiple methods of soil tillage, etc) but weeds continue to be the biggest challenge to establish these crops. This is especially evident where purpose grown biomass grasses are established on more marginal pasture lands and weed control is the largest deterrent to reaching full yield potential. As purpose grown biomass crops cannot compete financially for the higher class land and would only raise concerns in the 'food vs. fuel' debate, effective weed control in establishing grasses into former pasture is required.

Chemical control to assist in the establishment year of biomass crops is essential. Mechanical weed control is currently the only method for weed control in Miscanthus. However, mechanical control is very costly and labour intensive and it is not suitable for larger acreages, which we foresee in the future. In addition, there is no means for weed control in Ontario in solid seeded grasses such as switchgrass. Therefore, mechanical control of weeds in biomass crops is not suitable.

With no suitable weed control options, stand establishment may be compromised. Research from the University of Guelph has shown that the overwintering capability of Miscanthus is strongly correlated to height and circumference of the plant entering the initial winter. This indicates that if the grasses do not establish fast enough to compete with early weed pressure, first year growth is delayed and survival of the crop in the initial winter may be compromised. If stand survival is compromised producers will have to incur high replacement and labour costs.

In addition, observations from this OSCIA project, trials by the University of Guelph and the University of Illinois have all demonstrated that poor weed control during establishment can compromise second and third year yields. If stands are grown under high weed pressure, plants are smaller in the initial year and must recover in subsequent years. This increases the time it takes to reach the full yield potential of the stand into the second and third year of growth. Chemical weed control for dedicated biomass crops is necessary as there are currently no realistic means of weed control on large biomass crop fields, stand establishment is compromised with poor weed control in the initial year and high weed pressure can limit yield potential in the first several years of crop establishment.

I would be pleased to further discuss this project and our desire for chemical weed control options. Please do not hesitate to contact me if you have questions.

Sincerely,

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Appendix F- Events and Field Tours available to Co-operators during the Program

Event	Date(s)	Details
Canada's Outdoor Farm Show Biomass Demonstration Plots	September 13-15, 2011, September 11-13, 2012, September 10-12, 2013	Producers were invited to visit the biomass booth (including harvesting demonstrations in 2013) and discuss biomass experiences and opportunities with potential new biomass producers
Biomass Producers' Knowledge Exchange	January 25-26, 2012	All program participants were invited to take part in discussions about their field experiences related to agronomy, policy, biomass supply and handling logistics, markets and end uses.
Ontario Biomass Field Tours	September 26-October 3, 2011, September 17-25, 2012	Field tours stopping at 3-4 locations per day across the province. Open to anyone interested in biomass, stops along the tours featured many of the producers in the biomass program.
Agricultural Biomass Dinner & Reception at Greening Rural Opportunities Summit	March 5, 2013	Networking dinner focused on market development for producers and related industry, research and government representatives.

Appendix G- Field Plot Benefits to Other Research Projects

Several of the field plots established by this program have provided additional benefit to other biomass research programs at the University of Guelph and Trent University.

1. **Grassland Habitat Management Study**- This project was a partnership between OSCIA and the Ecology and Conservation Group at Trent University. The objective of this study was to identify the suitability of hayfields, pastures and native grasses grown for biomass for providing grassland habitat. Masters student Nicole MacDonald collected vegetation and wildlife observations from the plots of 11 of the participants in the biomass program. Nicole is also working in coordination with Christine Schmalz, Environmental Programs Co-ordinator, OSCIA. Preliminary results suggest that Bobolink are not using biomass grasses for breeding habitat.

2. **Biofuel Grass Ecology Study-** This is an OMAF and MRA funded study being run by Dr. Heather Hager, School of Environmental Sciences, University of Guelph. Dr. Hager used the plots of six of the participants in the biomass program to monitor the growth and ecology of new biofuel crops (mainly switchgrass and Miscanthus). Heather used non-destructive sampling to measure crop expansion at field margins. Field work was conducted between 2012-2013. Results from 2012 were that switchgrass and Miscanthus tillers rarely expanded beyond a few meters and 0.5 m, respectively, beyond the field margins.

3. **Comparison of Bioenergy Feedstocks for Anaerobic Digestion Study-** This study is being conducted by the University of Guelph at the Ridgetown campus. Masters student Kurtis Baute and his supervisor Dr. Brandon H. Gilroyed with the objective to assess the potential of switchgrass as a bio-energy feedstock for anaerobic digestion. Small quadrats of switchgrass were harvested through the 2013 growing season to assess yield and biogas production potential on two plots included in this biomass program (of 4 research sites in total). Research will continue in 2014.

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