

Planting and Growing Miscanthus



Best practice guidelines for growing miscanthus under the Bioenergy Scheme (BES).

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1. Glossary of terms

ha	Hectare
kg	Kilogram
MJ	Mega-joule (one thousand joules)
MW	Mega-watt
MWe	Mega-watt electrical capacity
Rhizome	Modified underground stem used for crop propagation
Soil Diffuse pollution	Soil Diffuse Pollution is a pollution event not from a single point source pollution event (e.g. a pesticide spillage on a farm into a field drains) but from a series of non point source pollution events over a catchment area. Examples are sheet run off from fields or seepage of nutrients from soil into ground water. Diffuse source pollution events are often individually minor, but collectively significant.

2. Introduction

This booklet is designed to introduce farmers to a new crop. It is intended as a guide on the most appropriate location, land preparation, planting techniques and crop management required to grow miscanthus as a crop destined for energy use. The booklet summarises ongoing current research and best practice. This is the second version and will be further updated as more experience in the establishment and growing of the crop is gained. The booklet should be read in conjunction with the Department of Agriculture, Fisheries & Food (DAFF) Bioenergy Scheme terms and conditions. If you require a copy, please visit the DAFF website at www.agriculture.gov.ie

Important Notice:

The Department of Agriculture, Fisheries and Food cannot accept responsibility for any loss or inconvenience arising from the material contained in this Best Practice Manual. Applicants are advised to obtain independent technical advice on the planting, growing and management of miscanthus crops.

Applicants must adhere to all provisions of Statutory Instrument No. 101 of 2009, European Communities, (Good Agricultural Practice for Protection of Waters) Regulations 2009.

3. Why grow energy crops?

The convergence of the increased cost of oil, the volatility of oil supply and the need to reduce carbon dioxide emissions, has focused renewed attention on renewable energy materials in recent years. Furthermore, important and challenging EU targets exist relating to the development and penetration of renewable energy and biofuels.

The Government White Paper on Energy “*Delivering a Sustainable Energy Future for Ireland*” sets out the framework for energy policy to 2020 under three main pillars, (1) security of supply, (2) sustainability and (3) competitiveness. One of the main policy goals in the White Paper is to accelerate the growth of Ireland’s renewable energy resources including bioenergy (biofuel and biomass). Specific bioenergy targets include:

- A minimum 5% market penetration of renewables in the heat market by 2010 and 12% by 2020
- Increase the use of biofuels in transport fuel to 5.75% by 2010 and 10% by 2020 (This has now been overtaken by the Biofuel Obligation Scheme which obliges Irish fuel Suppliers to include 4% biofuel by 2010)
- Achieve 30% co-firing with biomass at the 3 peat power plants by 2015;
- Target 800 MW of CHP (Combined Heat and Power) by 2020 with an “emphasis on biomass fuelled CHP”

To achieve the above targets, a significant increase in the supply of biofuel and biomass will be required.

Furthermore, in April 2009, the EU published a Directive¹ to increase the use of energy from renewable sources. The Directive forms part of the EU Climate Change-Energy Package and mandates Ireland to achieve a 16% share of energy from renewable sources by 2020 and a 10% target for renewable energy in transport by the same date.

Energy crops including miscanthus can make a significant contribution towards increasing the supply of indigenously produced biomass. The main potential uses for miscanthus are in the production of heat, CHP or electricity power on a range of scales from large power stations (30MW+) requiring hundreds of thousands of tonnes of biomass annually, to small-scale systems (on-farm or single building) requiring just a few dozen tonnes during winter months.

4. Alternative end uses

¹ Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

Other markets for Miscanthus exist apart from the energy market. Other end-uses include high value equine bedding and sustainable composite materials for markets such as the production of biodegradable plastics and fibres for car parts. New markets will continue to develop and it is possible that in the future, transport fuels such as ethanol may be produced from biomass crops such as miscanthus. Alternative end uses are not eligible for funding under the Bioenergy Scheme.

5. What is Miscanthus?

Miscanthus species originate in Asia and they are perennial, rhizomatous grasses with lignified stems (resembling bamboo). Once the plants are established (typically requires 2-3 years) some genotypes such as the triploid hybrid *M. x giganteus* have the potential for very high rates of growth, growing stems that are >3m within a single growing season. Miscanthus may be familiar as a flowering garden ornamental. These ornamental forms are generally different to those that are of value for biomass production.

Miscanthus is planted in spring and once planted can remain *in situ* for at least fifteen years. The miscanthus leaves fall off in the winter, contributing to the development of soil humus and nutrient recycling. Miscanthus produces bamboo-like canes during late spring and summer which are harvested in late winter or early spring.

Long-term average harvestable yields from a mature crop (i.e. excluding the first 3 years – have exceeded 16 dry tonnes per hectare per year (t/ha/yr) at the most productive experimental sites in the UK. While there is limited information on yields of miscanthus in Ireland as yet, experience to date in Ireland and the UK suggest that the crop has the potential to make an important contribution to Ireland's commitment to energy generation from renewables.

This growth pattern is repeated every year for the lifetime of the crop. Miscanthus spreads naturally by means of underground storage organs known as rhizomes. However, their spread is slow and there is little risk of uncontrolled invasion of hedges or fields. These rhizomes can be split and the pieces re-planted to produce new plants. All propagation, maintenance and harvest operations can be done with conventional farm machinery.

6. Annual growing cycle

The growth pattern of the crop is quite simple. It produces new shoots annually and these usually emerge from the soil during April. These shoots develop into erect, robust stems, which reach 1 - 2 m in height by late August of the year of planting, with a diameter of 10 mm. The stems are usually unbranched and contain spongy pith.

From late July the lower leaves senesce as canopy closure prevents sufficient light penetration. Following the first air frost in autumn, senescence accelerates and nutrients move back to the rhizome. Leaves then fall and a deep leaf litter develops. Any remaining foliage dies and the stems dry to a relatively low moisture content (30-50%) during winter. By February, free standing, almost leafless, canes remain and it is these which are harvested mechanically. This growth cycle is repeated once spring-time temperatures increase again. From the second season onwards the crop can be expected to achieve a maximum height of 2.5 - 3.5 m.

7. Where to Grow Miscanthus?

Crop requirements

Soils

From experience gained in the establishment and growing of the crop in Ireland since 2006, it is clear that the more productive and fertile soils are more suitable in terms of growth vigour and ease of establishment than the more marginal sites. The crop is tolerant to a wide range of pH values, but the optimum is between pH 5.5 and 7.5. Miscanthus is harvested in the winter or early spring and therefore trafficability of the site at this time of year is an important factor to consider. It is essential that the site does not get excessively waterlogged during this period, as this may limit accessibility for harvesting machinery and cause damage to the soil structure. Growing miscanthus on heavy clay, poorly drained or peaty soils in most circumstances should be avoided.

Temperature

The potential cropping zones for miscanthus are quite widespread. Miscanthus does not grow at low temperatures below a threshold of 6°C. This is considerably lower than for maize and therefore the potential growing season is longer. Late spring frosts which destroy early spring foliage and effectively reduce the duration of the growing season are the major constraint to long season growth in *M. x giganteus*.

Water availability

Annual rainfall and soil water retention will strongly influence the yield of miscanthus at any site. Miscanthus possesses good water use efficiency when considered on the basis of the amount of water required per unit of biomass and miscanthus roots can penetrate and extract water to a depth of around 2m. However, to achieve high yields the crop may need more water than the crops that it may replace. In addition, a dense canopy means that

20-30 % of rainfall is intercepted by, and evaporates off the leaves and never reaches and infiltrates into the soil. Limited soil water availability during a growing season will prevent the crop from reaching full potential yield in that year; a loss of 90 kg of biomass per hectare for each millimetre of soil water deficiency has been calculated. Irrigation is not justified by the value of increased biomass obtained. In times of severe drought, the foliage of miscanthus will first show leaf rolling and then die back from the leaf tip. This will reduce yield in the year of drought but in all cases experienced in the UK to date the crop will survive and re-grow the following year.

Site selection

Applications for the Bioenergy Scheme must be linked to an energy end use (either on or off-farm) that is within reasonable distance of the crop.

Since the miscanthus will exist on the site for at least 15 years and can reach up to 3.5m in height, its impact on the local landscape (particularly if the site is close to a footpath or a favourite view) or an adjacent landowner or homeowner needs to be considered. Impacts on wildlife, archaeology and public access must also be addressed prior to cropping. In addition, the impact of harvesting machinery on the soil should be considered. Soil diffuse pollution should be prevented by ensuring soil compaction is minimised and soils retain good structure.

Some eligible land can remain uncropped with miscanthus in order to accommodate environmental, landscape and access issues, with no impact on the amount of grant awarded. The positioning of open ground needs to be considered in terms of sympathetic landscape views and access issues. Where appropriate, open ground can be positioned alongside neighbouring houses to protect their view.

Miscanthus has the potential to encourage a greater diversity of wildlife than some agricultural crops, particularly if located in an area of low conservation value or as a link between existing habitats. It may also provide an area of sheltering habitat. Care must be taken to prevent this new habitat from adversely affecting existing conservation areas.

8. Planting

Pre-planting requirements

Thorough site selection and preparation is essential for good establishment, ease of subsequent crop management and high yields. As the crop has the potential to be in the ground for at least 15 years, it is important that it is established correctly to avoid future problems.

The first step, before planting, is to spray the site with an appropriate broad spectrum herbicide (e.g. glyphosate) for controlling perennial weeds. **It is vital that proposed sites should be cleared of perennial weeds before any planting takes place.** The site should then be ploughed. Early ploughing will allow any frost activity to break down the soil and may also help prevent 'ley'

pests such as the larvae of two moths; the common rustic moth and the ghost moth attacking the newly established plants.

Later in the spring from March to April, the site should be rotovated or power harrowed immediately prior to planting. This will improve soil aeration and establishment by aiding good root development. Rolling post-planting will also improve soil root contact and the effectiveness of any residual herbicides applied.

Planting material

Using high quality and healthy rhizomes is essential to obtaining good crop establishment. Rhizomes should be of a young age class and not regenerated from old cane crops. Proper storage and sensitive handling and transport of rhizomes prior to planting is also essential to ensure viability. For plant health reasons, miscanthus rhizomes should only be sourced from European countries.

Methods of Propagation

The main method of propagation currently used in Ireland is rhizome division although micro-propagation is another method that could be used.

Rhizome division is favoured because it is less expensive and generally produces more vigorous plants. To produce new planting material, two or three-year-old plants are split whilst dormant, using a rotary cultivator, and the rhizome pieces collected for re-planting.

Rhizome pieces must have at least 2 to 3 shoot initials, (buds with sharp points)' and must be kept moist before re-planting. This is best achieved by keeping rhizomes under cold-storage conditions (<4°C), but they will remain viable in the field for a short period of time, if stored in a heap and covered with moist soil.

Planting density

Rhizomes need to be planted at a soil depth of 5-10cm and at an appropriate rate to achieve a final plant density of 10,000/ha. The planting rate should allow for some establishment losses while still providing the plant density of 10,000/ha required to achieve optimal yields from year three onwards and effective weed suppression through competition. Recent improvements in rhizome extraction and selection have resulted in much higher establishment rates (typically >80%).

Planting Date

The optimal planting time for rhizomes is from March to April and this is strongly recommended as early planting takes advantage of spring-time soil moisture and allows an extended first season of growth. This is important, because it enables larger rhizome systems to develop. This results in a more robust rhizome in future years, and allows the crop to tolerate drought and frost better.

Planting can continue into May and may still be successful, however, crops planted later than the optimum planting time increases the likelihood of problems with crop establishment.

Planting equipment

There have been significant developments in miscanthus planting machines in the past few years.

A number of specialist automatic planters have been developed including two and four row planters. These machines have a high work-rate and the planting density can be controlled.

A number of manually operated planters have also been developed. These planters allow for accurate placement of rhizomes and good precision in terms of plant spacing.

For successful crop establishment, it is essential that rhizomes have good soil cover and contact, the latter being achieved by rolling directly after planting.

9. General crop management

Fertiliser requirement

The annual fertiliser demands of the crop are low due to good nutrient use efficiency and the plant's ability to re-cycle large amounts of nutrients into the rhizomes during the latter part of the growing season. The level of nutrients applied should be matched with the nutrient off-take by the crop and the soil nutrient status. Further advice on nutrient requirements for miscanthus is available from the Teagasc Information Sheet 'Nutrient Guidance for Energy Crops'.

Weed control

Weeds compete with the crop for light, water and nutrients and can reduce yields. Weed control in the establishment phase of the crop is essential, because poor control can severely check the development of the crop and lead to poor crop establishment.

It is vital that an appropriate weed control strategy is undertaken during the initial years of crop establishment. Such a strategy should ensure that:

- **proposed sites are cleared of perennial weeds before any planting takes place**
- **measures to control annual weeds are undertaken post-planting as required during the initial years in the establishment of the crop.**

An annual spring application of a broad-spectrum herbicide may be needed to control grass weeds such as scutchgrass and annual meadow-grass and broad-leaved weeds with early season vigour in the second establishment

year and possibly in subsequent years. Glyphosate and paraquat have been used in the dormant period before the initiation of spring growth ***but extreme caution is advised, as they will cause severe damage to the crop if they are timed incorrectly or applied inappropriately.*** Spraying glyphosate on first year crops during the dormant period should be accompanied by topping within 48 hours of application. Applicants should receive independent technical advice with regard to the application of herbicides.

Once the crop is mature (i.e. from the summer of the second or third year, depending on site and climate), weed interference is effectively suppressed, initially by the leaf litter layer on the soil surface and subsequently by the closure of the crop canopy, which reduces the light penetrating into the understorey. Weeds that do survive offer little competition to the crop.

It should be noted that herbicide application must not be made on miscanthus crops greater than 1 metre in height and the crop cannot subsequently be used for food or feed. The Department of Agriculture's Pesticides Control Service (PCS) has issued off-label approval for some herbicides used for cereals, grass and maize. Before choosing a product all growers should contact the PCS to make sure the product has the appropriate approval for use on miscanthus. Visit: <http://www.pcs.agriculture.gov.ie>

Further information on weed control in Miscanthus is available from Teagasc - Tillage No 10 Factsheet, 'Miscanthus Weed Control'. Visit: www.teagasc.ie

Infilling/patch-planting

In situations where significant gaps remain in the crop following the 1st year of establishment, and where the crop is likely to have 'sparse/gappy' areas, patch-planting/infilling will be required to ensure full establishment and to allow the crop to reach its full potential

Pests and diseases

Miscanthus species are susceptible to pests and diseases in the areas to which they are native (Asia) but, as yet, none of these have been reported in the UK or Ireland. Stem basal diseases may infect stems in the autumn or winter, reducing stem strength.

There are no reported insect pests in Europe that have significantly affected the production of miscanthus. However, two 'ley pests', the common rustic moth and ghost moth larvae feed on miscanthus and may cause problems in the future.

Wire worms can be a problem when Miscanthus is planted in some long term grassland sites.

The common rustic moth

The larvae feed from autumn until May on miscanthus grass roots and other grasses including cock's-foot. These larvae become adults after overwintering. They can be found resting in a wide variety of habitats

concealed in ground vegetation by day, becoming active after dark. They are particularly attracted to flowers of the common ragwort and marsh grasses.

The ghost moth larvae

Ghost moth larvae are subterranean and rarely seen, feeding on roots of the miscanthus and other grasses. It takes two years to develop into a moth, thereby over-wintering twice. Ghost moth adults are often found in grassy embankments, fields and hillsides. The males can often be in flight at dusk on warm evenings swaying up and down amongst tall grassy vegetation.

Rabbits

Rabbits can pose a serious problem to establishing a new miscanthus crop as they like to feed on the fresh emerging leaf as the crop grows initially. A high level of rabbit grazing can result in crop failure. Fencing may be required if rabbits pose a threat to the establishment of the crop.

10. Harvesting and Storage

Harvesting

The annual harvest of the stem material **can be carried out between January and March** using a number of different machines depending on availability and requirement of the end market. For energy cropping, a baled product is the most desirable. However, this type of harvest involves two operations before the bale is produced, and this can result in high biomass losses.

The crop is first cut with a mower conditioner. Conditioning breaks up the rigid stems, allowing accelerated moisture loss, and provides a light, rectangular windrow. This not only makes baling easier, but also helps in the drying of the material, by increasing the surface area and increasing air circulation in the swath.

There are a number of different types of balers, each producing different bales (e.g. rectangular, round and compact rolls), suitable for different scales of energy combustion. Large rectangular and round balers are capable of producing bales with a dry matter density of between 120 and 160 kg/m³ and weighing between 250 and 600 kg. These balers generally have a capacity of 1 ha/hr.

A critical factor for an energy crop is the moisture content at harvest. The drier the crop, the higher the energy yield and bale value. Moisture contents as low as 15% have been obtained in the UK, with the maximum being about 40%. By conditioning and allowing to dry in the field in windrows, the stem moisture content can be halved.

Storage

The storage of Miscanthus bales should follow the same rules as the handling and stacking of any bales produced on farms. Bales should be stacked safely. Thus, stacks should be sited;

- Away from public roads and footpaths to reduce the risk of fire from discarded cigarette ends,
- Away from overhead power lines,
- Well away from residential properties and where several stacks are sited together they should be built in a line across the prevailing wind and not less than 24 meters apart.

All stacks must not be higher than 1.5 times the shortest baseline measurement. Bales should be stacked on the unstrung sides and overlap bale layers must be included at regularly intervals, as well as binding in the vertical columns.

11. Calendar of Activity

	Year	Period	Activity
PREPLANTING	-1	Jan - Jun	<ul style="list-style-type: none"> • Consider site selection and liaise with neighbours, other growers of the crop, end-users, etc. • Prepare evidence of market for miscanthus • Prepare and submit Establishment Grant application
		Aug – Nov	<ul style="list-style-type: none"> • Familiarise yourself with the management of miscanthus by reviewing literature on the crop.
ESTABLISHMENT	1	Jan – Apr	<ul style="list-style-type: none"> • Apply glyphosphate to control perennial weeds • Plough • Rotovate or power harrow soil immediately prior to planting. • Planting
		Apr – May	<ul style="list-style-type: none"> • Apply nutrients but only if required • Herbicide application while crop height below 1m
	2	Feb – Mar	<ul style="list-style-type: none"> • First year growth not usually harvested
		Apr – May	<ul style="list-style-type: none"> • Apply nutrients if required • Herbicide application while crop height below 1m
CROPPING	3+	Feb – Mar	<ul style="list-style-type: none"> • Harvest previous years growth with mower conditioner • Bale and stack
		Apr – May	<ul style="list-style-type: none"> • Monitor crop nutrient and apply nutrients if required • Herbicide application if required

12. Yield

Yields will vary according to age of the crop and environmental factors specific to any one particular site. The crop will take two to three years to reach a mature yield (up to five years on marginal sites). After this initial yield-building phase, the crop will continue for many years (at least 15 years).

The yield from the first season's growth, at 1-2 t/ha, is not worth harvesting. The stems do not need to be cut and so the stems may be left in the field until the following season. **However, if spring-time applications of translocated herbicides are planned then the miscanthus stems should be flailed in order to avoid any risk of crop uptake.** From the second year onwards the crop is harvested annually.

The second year harvestable yields may range from 4-10 t/ha and those in the third and subsequent years would range between 10 -13 t/ha or possibly more. Harvestable yields reach a plateau after 3-5 years. There can be large variation in yields both in the yield building phase duration and also in the plateau phase and this depends on planting density, soil type and climate. Your advisor should be able to advise on the suitability of an individual site in terms of potential yield production.

Removal of miscanthus

Miscanthus can easily be removed from an existing site by the application of a post-emergence non-selective herbicide such as glyphosate. This is followed by rotovation of the crop to eliminate the miscanthus rhizome.

13. Energy value

Miscanthus has a net calorific value, on a dry basis, of 17 MJ/kg, with a 2.7% ash content. The energy value of 20 t of dry miscanthus would be equivalent to that of 8 t of coal. Growing miscanthus as a fuel is very energy efficient. A UK lifecycle energy analysis determined an energy ratio of over 30 for miscanthus i.e. for every unit of energy expended in producing the crop over 30 units of energy are obtained.

Miscanthus can be used for large-scale electricity power stations or for small scale heat production. Existing straw burning technology can be used to meet on-farm heat requirements.

14. Environmental considerations

Compared to arable or intensive grass which miscanthus is most likely to replace, several studies have demonstrated that the environmental impact is likely to be benign.

- **Low Input requirement.** Compared to arable crops, miscanthus has a very low agro-chemical requirement. Use of pesticides other than herbicides and chemical fertilisers are not recommended. Pesticide use is not generally recommended for miscanthus after the establishment phase. As the site is only cultivated once, reductions in soil disturbance and erosion can also be achieved compared with conventional crops.
- **Carbon Neutral.** Miscanthus takes up as much carbon as is released when it is burnt so there is no net increase in CO₂ into the atmosphere. Furthermore, some carbon is sequestered into the soil in the form of root and rhizome growth. Carbon budgets which include the use of fossil fuels in the transportation of materials indicate that the entire cycle releases less carbon than when compared with fossil fuel combustion cycles.
- **Landscape** Care should be taken when choosing a site to plant miscanthus. In addition, careful siting of open ground can minimise impacts on neighbouring lands.
- **Biodiversity** A number of studies have shown that miscanthus can enhance biodiversity for a range of wildlife including a number of bird species, earthworms, spiders and mammals compared with growing arable crops. Miscanthus provides cover for wildlife for most of the year because, although the crop is harvested annually, it is harvested shortly before the following year's growth begins. This cover can act as a wildlife corridor linking existing habitats.