PLANTING AND GROWING
MISCANTHUS

BEST PRACTICE GUIDELINES
For Applicants to DEFRA’S Energy Crops Scheme
## Contents

- **Introduction** 3
- **Why Grow Energy Crops?** 4
- **What is Miscanthus?** 5
- **Annual Growing Cycle** 6
- **Where Will Miscanthus Grow Well?** 7
- **Site Selection and Planning** 8
- **Pre-Planting Requirements** 8
- **Planting Material** 9
- **Planting Equipment** 10
- **Fertiliser Requirements** 12
- **Weed Control** 12
- **Pests and Diseases** 14
- **Harvesting** 14
- **Energy Value** 16
- **Biodiversity** 17
- **Useful Contacts and References** 18
- **Reports and Publications** 18
Introduction

This booklet has been produced to introduce farmers to a new crop. It gives guidance on the most appropriate location, land preparation, planting techniques and crop management required to grow miscanthus as an energy crop. The booklet summarises current research, which is ongoing, and these guidelines may be modified as further experience is gained. Please check that you have the latest version of the booklet with the DEFRA office at Crewe.

This booklet should be read in association with the Energy Crops Scheme explanatory booklet, ‘Establishment grants for short rotation coppice and miscanthus.’
Why grow energy crops?

The market for energy crops - crops which are grown specifically to be harvested and burnt in power stations or heating systems - is now developing in response to the need for atmospheric carbon dioxide (CO₂) abatement. The UK Government identifies biomass-derived energy as one of the ways that it can achieve its obligations to the Kyoto Climate Change Protocol of reducing greenhouse gas emissions by 12.5%. It has a target to generate 10% of the nation's electricity from renewables by 2010, and aims to reduce CO₂ output by 20% relative to 1990 levels. These targets could mean the generation of 500 - 1000 MWₑ from biomass by the year 2010, an undertaking that would require as much as 125,000 hectares of energy cropping.

One energy crop is miscanthus. Grants to establish this crop can be obtained from DEFRA under the England Rural Development Programme (Energy Crops Scheme). For details of the grant scheme, ask for a booklet from the DEFRA office at Crewe (see page 18), or see the DEFRA ERDP website www.defra.gov.uk/erdp/default.htm
What is miscanthus?

Miscanthus species are woody, perennial, rhizomatous grasses, originating from Asia which have the potential for very high rates of growth. Miscanthus may be familiar to many as a flowering garden ornamental, but it is the non-flowering forms that are of interest agriculturally.

Miscanthus is planted in spring and canes produced during the summer are harvested in winter. This growth pattern is repeated every year for the lifetime of the crop, which will be at least 15 years. Miscanthus differs from short rotation coppice willow (an alternative energy crop) in that it gives an annual harvest and thus an annual income to the farmer. Miscanthus spreads naturally by means of underground storage organs (rhizomes). However, their spread is slow and there will not be any 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. In the UK, long-term average harvestable yields from a mature crop have exceeded 13 dry tonnes per hectare per year (t/ha/yr) at the most productive experimental sites. These high yields suggest that the crop has the potential to make an important contribution to the UK’s commitments to energy generation from renewable sources.
The growth pattern of the crop is 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, which have an appearance similar to bamboo canes, are usually unbranched and contain a solid pith.

From late July the lower leaves start to dry. Crop drying accelerates during autumn, as nutrients move back to the rhizome. Leaves then fall and a deep leaf litter develops. Any remaining foliage dies following the first air frost, 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.
Where will miscanthus grow well?

More experience is needed of yields under a wide range of soil conditions, but current information suggests that most lowland agricultural sites in England should be suitable for miscanthus cropping, with the highest yields coming from deep, moisture retentive soils.

Key determinants of yield are sunshine, temperature and rainfall. The old ‘maize growing zone’; south of a line drawn between the Bristol Channel and the Wash, will satisfy the environmental requirements for high yield, but many lowland sites north of this line will also be suitable. Within these areas, annual rainfall levels will effect yield.

Soils

Miscanthus has been reported growing, and producing high or reasonable yields on a wide range of soils - from sands to high organic matter soils. It is also tolerant of a wide range of pH, but the optimum is between pH 5.5 and 7.5. Miscanthus is harvested in the winter or early spring and therefore it is essential that the site does not get excessively waterlogged during this period, as this may cause problems with the harvesting machinery.

Temperature

The potential cropping zones for miscanthus are quite widespread. Photosynthesis, and therefore plant growth, is not achieved at very low temperatures. However, the threshold for miscanthus photosynthesis (6°C) is considerably lower than for maize and, therefore, the potential growing season is longer. The major constraint to long season growth is late spring frosts which destroy early spring foliage and effectively reduce the duration of the growing season.

Yield as plants mature

The yield from the first season’s growth, 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. From the second year onwards the crop is harvested annually. The second year harvestable yields may range from 4-10 t/ha (occasionally up to 13 t/ha), and those in the third year would be between 10 -13 t/ha or more. Peak harvestable yields of 20 t/ha/yr have been recorded at a number of sites. The reason for the variation depends on planting density, soil type and climate. At sites where moisture supply or exposure limit yield, there may be a longer ‘yield-building’ phase.

Long term yield

The long-term average results from a multi-site study in England show that harvestable yields from good sites, including clay, clay loam and peaty soils, exceed 13 t/ha/yr. Yields from sites at 300 m altitude in the Yorkshire Wolds (ADAS High Mowthorpe) and on free-draining sandy soils (ADAS Gleadthorpe) have been much lower at 9 t/ha/yr or even less.
Site selection and planning

As with any crop that is likely to be in the ground for a number years, it is important that a number of issues (such as landscape, wildlife value, archaeology and public access) are considered in the selection of a site. Miscanthus, once established can grow to 3.5 m in height, it is therefore important to consider the visual impact this might have on the local landscape, especially if the site is close to a footpath or a favourite local view.

Miscanthus has the potential to encourage a greater diversity of wildlife than some agricultural crops. This potential is most likely to be realised if it is grown as one component of a mixed cropping pattern and if it is located in an area of low conservation value or as a link between existing habitats. Care must be taken to prevent this new habitat from adversely affecting existing habitats, especially those within existing conservation areas.

Details of land which is eligible, the environmental standards you must observe and the assessment of your application which will take place can be found in the Energy Crops Explanatory Booklet. If you are unsure about any of these requirements you should seek advice from DEFRA’s office at Crewe.

Pre-planting requirements

Thorough site 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, in the autumn before planting, is to spray the site with an appropriate broad spectrum herbicide (e.g. glyphosate) for controlling perennial weeds. The site should be sub-soiled if necessary to remove compaction, then ploughed and left to over-winter. On light soils it may be more appropriate to spring plough. This will allow frost activity to break down the soil further. This may also help prevent ‘ley’ pests attacking the newly established plants, as any larvae or eggs already in the soil from the previous crop will have insufficient food over the winter to survive. In the following spring the site should be rotovated immediately prior to planting. This will not only improve establishment by aiding good root development but will also improve the effectiveness of any residual herbicides applied after planting.
Planting material

Two methods of propagation are currently used in the UK - rhizome division and micro-propagation. 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. A 30-40 fold increase in plants can be achieved this way over a period of 2-3 years, depending on soil conditions.

Rhizome pieces must have at least 2-3 ‘buds’ and must be kept moist before re-planting. This is best achieved by keeping rhizomes under cold-storage conditions, (<4°C) (possibly for up to a year) but they will remain viable in the field for a short period of time, if stored in a heap and covered with moist soil. The optimal planting density for either propagation system is 20,000 plants/ha, but this may vary slightly from site to site. Rhizomes need to be planted to allow for some expansion of the plant during the life of the crop and at a soil depth of 5-10 cm. The optimal planting date for rhizomes is March-April. 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. These are more robust in future years, and allows the crop to tolerate drought and frost better.

Note: the import of miscanthus rhizomes from third countries, other than European and Mediterranean countries is prohibited. The European Commission may consider derogations to the ban. For further advice contact DEFRA’s Plant Health Division (see address on page 18).
Planting can be carried out using semi-automatic potato planters, manure spreaders or bespoke planters. There is still some uncertainty as to which is the best planting method, because local site conditions can dramatically affect performance. However, use of the potato planter or bespoke planter are recommended, as the results below indicate.

**Potato planter**

For rhizomes destined for use in the potato planter, grading is required to remove rhizomes which will not fall down the planting tube or have less than 2-3 ‘buds’. Once graded, the operator of the potato planter places rhizomes into a cup or drops them down a planting tube. The distance between plants is governed by the speed of a land wheel. As the rhizomes enter a furrow opened by a share, the soil is ridged over the rhizomes. The potato planter should be followed by a heavy roller to aid soil consolidation. The work rate achieved is low (0.3 ha/hr). This technique ensures accurate placement and good depth control, both of which are important for good establishment success.

**Results** - In a four-site study, this method achieved a work rate of 0.3ha/hr and an establishment rate of 95%.
Manure spreader

This is the least favoured option. A manure spreader can be used simply by filling the hopper with rhizomes or a rhizome/soil mixture, and then spreading the material at a pre-determined rate to attain the desired plant density. Following broadcasting, the rhizomes are then cultivated into the soil, to a target depth of 10-15 cm and the soil rolled, for good rhizome-soil contact. This must be done as quickly as possible, to reduce moisture loss in the exposed rhizomes on the soil surface. This method produces a faster work rate (3 ha/hr), but it is an imprecise method due to the lack of control of plant spacing and depth. Perhaps most importantly, the rhizomes are not planted into a fine tilth, so even following rolling, contact with the soil may be very poor and the rhizomes prone to drying out.

Results - In the same four-site study, a work rate of 3ha/hr, but only 22% establishment was achieved with this method.

Bespoke planter

A machine has been designed specifically for planting miscanthus by Hvidsted Energy in Denmark. This machine works by planting two rows of rhizomes into a shallow furrow opened by shares. Once planted, the soil is moved back to cover the rhizomes and then rolled. The machine can be calibrated, to plant different densities, if required.

Results - a work rate of 1.25ha/hr and an average establishment rate of 92% in the four-site study.
Fertiliser requirements

The annual fertiliser demands of the crop are low. This is due to good nutrient use efficiency and the plant’s capability to re-cycle large amounts of nutrients into the rhizomes during the latter part of the growing season. As a consequence, nutrient off-take at harvest is low, as shown in Table 1. Since the leaves predominately remain in the field it is only necessary to account for the amount of nutrients removed in the stems. The nutrient requirements during the following seasons are met by leaf litter decomposition, natural soil nutrient reserves, rhizome reserves and atmospheric depositions. Mature rhizomes tend to store more nutrients than the crop needs, so after the first 2 years, only a small quantity of additional micro-nutrients may be required. For good miscanthus yields a minimum phosphorus and potassium soil index of 1 should be aimed for and soil nitrogen supply should exceed 150 kg/ha in each of the first 2 seasons. When nutrients are needed in the first 2 seasons, this could come from farm-yard manure or sewage sludge.

Codes of Good Fertiliser Practice should always be followed.

<table>
<thead>
<tr>
<th></th>
<th>Stem</th>
<th>Leaf litter</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>88</td>
<td>47</td>
</tr>
<tr>
<td>P</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>K</td>
<td>95</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 1. Nutrient ‘off-take’ (kg/ha) for an ‘average crop’ consisting of 13.5 t/ha of stems and 4.5 t/ha leaf litter

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. It is vital that proposed sites should be cleared of perennial weeds before any planting takes place. DEFRA’s Pesticides Safety Directorate has given off-label approval for herbicides used for cereals, grass and maize to be used on miscanthus. Write to PSD (see page 18) or see www.pesticides.gov.uk/solaweb/solaweb.htm

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. A wide range of herbicides have been used effectively with no visible damage to the crop in Denmark and the UK. Following the establishment year, an annual spring application of a broad-spectrum herbicide may be needed to control grass weeds such as common couch and annual meadow-grass and broad-leaved weeds with early season vigour. Glyphosate and paraquat have been used in this dormant period between harvest and initiation of spring growth but they will cause severe damage to any new shoots which might have emerged. Once the crop is mature (i.e. from the summer of the second year), weed interference is effectively suppressed. This is initially due to the leaf litter layer on the soil surface and subsequently due to the closure of the crop canopy, which reduces the light penetrating into the under-storey. Weeds that do survive offer little competition to the crop. Since there are no labelled recommendations, all products used are at the users own choosing and the commercial risk is entirely theirs.
### Table 2  Herbicides which have been used successfully to control weeds in miscanthus

<table>
<thead>
<tr>
<th>Active Ingredient(s)</th>
<th>Data Source</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>atrazine</td>
<td>A</td>
<td>Gesaprim @ 2.5 l/ha</td>
</tr>
<tr>
<td>bromoxynil/oxy nil</td>
<td>A</td>
<td>Briotril @ 2.5 l/ha</td>
</tr>
<tr>
<td>bromoxynil/fluroxypyr/oxy nil</td>
<td>A</td>
<td>Advance @ 2 l/ha</td>
</tr>
<tr>
<td>clopyralid</td>
<td>A, B</td>
<td>Dow Shield @ 2.4 l/ha</td>
</tr>
<tr>
<td>dichlorprop</td>
<td>B</td>
<td>(667g/l of active ingredient) @ 5 l/ha</td>
</tr>
<tr>
<td>diflufenican/isoproturon</td>
<td>B</td>
<td>(100:500g/l of active ingredient) @ 3 l/ha</td>
</tr>
<tr>
<td>fluroxypyr</td>
<td>A, B</td>
<td>Starane 2 @ 2 l/ha</td>
</tr>
<tr>
<td>glyphosate^2</td>
<td>A, B</td>
<td>Roundup @ 3 l/ha</td>
</tr>
<tr>
<td>isoproturon</td>
<td>B</td>
<td>Tolkan @ 4 l/ha</td>
</tr>
<tr>
<td>metsulfuron-methyl</td>
<td>A, B</td>
<td>Ally @ 30g/ha</td>
</tr>
<tr>
<td>metsulfuron-methyl + bromoxynil / oxy nil^3</td>
<td>A</td>
<td>Ally @ 30g/ha + Deloxil @ 1 l/ha</td>
</tr>
<tr>
<td>metsulfuron-methyl+ fluroxypyr^3</td>
<td>A</td>
<td>Ally @ 20g/ha + Starane 2 @ 0.5 l/ha</td>
</tr>
<tr>
<td>MCPA</td>
<td>B</td>
<td>(750g/l of active ingredient) @ 5 l/ha</td>
</tr>
<tr>
<td>MCPA + MCPB</td>
<td>A</td>
<td>Trifolex-Tra @ 7.7 l/ha</td>
</tr>
<tr>
<td>mecoprop-P</td>
<td>B</td>
<td>Duplosan @ 6 l/ha</td>
</tr>
<tr>
<td>paraquat2</td>
<td>A</td>
<td>Gramoxone @ 4 l/ha</td>
</tr>
</tbody>
</table>

1. (A) ADAS, (B) Georg Noyé Institute of Weed control ‘Flakkebjerg’, Denmark.
2. Herbicides for use before miscanthus emergence.
3. Tank mixtures.
**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 has been reported in the UK. Commonplace cereal diseases known to occur in miscanthus include barley yellow dwarf virus (BYDV), which may limit yield. Also, 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, have been reported feeding on miscanthus and may cause problems in the future.

**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 reported in southern Europe - although the lowest moisture content achieved in the UK has been around 20%, with the average closer to 50%. This may be partly because, in the UK, plants are still in the vegetative phase when the first frost induces die back. By conditioning and allowing to dry in the field, the stem moisture content can be halved from 50% to 25%.
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 12 t of coal.
Within the area for which establishment grant is applied, up to 10% can be left as open ground where this is used for management or environmental purposes. The wildlife value of this crop could be increased by the inclusion of rides and headlands to increase the number and species of flora and fauna. The use of grass headlands around the crop will protect edge habitats which are particularly important for wildlife by preventing shading to existing habitat. Headlands may also act as a sacrifice crop for rabbits or deer to feed on and thus reduce any damage they may cause to the newly established crop and they will also improve the access to the site, particularly at harvest.
Useful contacts and references

Energy Crops Scheme
DEFRA
Electra Way
Crewe
Cheshire
CW1 6GL
Tel: 01270 754135

Pesticide Safety Directorate
Mallard House
Kings Pool
3 Peasholme Green
York
YO1 7PX
Tel: 01904 640500

Plant Health Division
DEFRA
Foss House
Kings Pool
1-2 Peasholme Green
York
YO1 7PX
Tel: 01904 641000

Reports and publications

Final Report for DEFRA projects are available from:
DEFRA
Chief Scientist’s Group
1A Page Street
London
SW1P 4PQ
Tel: 020 7904 6875

Text prepared by Peter Nixon and Mike Bullard of ADAS Consulting Ltd.
Booklet design by Folio Creative Communication Ltd.
Contacting DEFRA

If you have a query and are unsure about who to talk to in DEFRA, you can call the Helpline who will be pleased to help you to find the right person.

DEFRA Helpline: 08459 33 55 77 (local call rate)