

## Harvest techniques in Europe

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### 1. INTRODUCTION

Short rotation crops (SRC) for energy use in Europe include oil seed crops such as rape seed (*Brassica sp.*, 800,000 ha) and sunflower (*Helianthus annuus*, 91000 ha) and lignocellulosic crops further used as fuel such as the woody crops eucalyptus (*Eucalyptus globulus*, 500000 ha), willow (*Salix sp.*, 20000 ha), poplar (*Populus sp.*, 550 ha) and the herbaceous crops reed canary grass (*Phalaris arundinacea*, 4050 ha), sweet sorghum (*Sorghum bicolor*, 1500 ha), miscanthus (*Miscanthus sp.*, 400 ha) and hemp (*Cannabis sativa*, 350 ha) (Luger, 1997; Gustav Melin, Agrobränsle AB, Örebro, Sweden, pers. com). The introduction of new short rotation crops or an alternative use of already grown crops is often followed by the development of new technical equipment needed for establishment, management and harvest. If the cultivation of a new crop has much in common with conventional agriculture (i.e., reed canary grass, miscanthus) or forestry (i.e., poplar, eucalyptus) it may be possible to use existing machines and equipment without any or only minor modifications. However, if the growing system of the new crop (i.e., willow) does not resemble any existing crop, it may be necessary to make major modifications on existing machines or design and construct new machines. In this paper we exemplify this by presenting the harvest techniques used in some of the short rotation crops grown in Europe.

### 2. REED CANARY GRASS (*PHALARIS ARUNDINACEA* L.)

Reed canary grass (*Phalaris arundinacea* L.) is the most promising perennial grass to be grown for energy purposes in Sweden and annual production levels of 8.0 to 11.5 t dry matter per hectare (t DM ha<sup>-1</sup>) have been measured in fertilised trials (Hadders and Olsson, 1997). Studies have shown that the optimal time for harvest is in the following spring rather than in the growing season (Landström *et al.*, 1996; Hadders and Olsson, 1997). Several advantages can be recognised at delayed spring harvest: the crop has a low water content of 10–15%, nutrients have been translocated from shoots to rhizomes, the amounts of chlorine, sulphur and potassium are reduced (which improves fuel characteristics) and the ash content is reduced (Burvall and Landström, 1997; Burvall, 1997). However, delayed spring harvest limits the time-period available for harvest from the point when soil is dry enough to carry the harvester to the point when new shoots have reached a height of 10–15 cm.

For reed canary grass harvesting standard equipment for hay harvesting is used. To avoid losses of material from the dry and fragile crop, low driving speed and the use of a windrower that allow careful handling are recommended (Olsson, 2003). Keeping the stubble low is important. A stubble height of 10 cm instead of 5 cm can reduce the dry matter yield with 20% (Pahkala, 1998). After harvest the grass is baled, preferably as square high density bales. The bales can be stored in the field but need to be covered and protected from soil moisture.

Bales intended to be used for pellets production, where demand on low moisture content is higher, are preferably stored in a barn.

### 3. MISCANTHUS (*MISCANTHUS SP.*)

Research on harvesting of miscanthus in Europe has been conducted mostly in Austria, Germany, Denmark, the Netherlands and Great Britain. Miscanthus is a perennial crop that is harvested every year. The establishment is conducted by planting rhizomes with specific machines (Jørgensen, 2001). Harvest is possible when the moisture content is 12-15% or higher if drying in storage is feasible (Venturi *et al.*, 1999). Another advantage with spring harvest is that the mineral content is lower, but on the other hand the biomass yield decreases. Therefore, harvest during February-April has prevailed especially in north Europe (spring harvest), though in south Europe autumn harvest is possible (Walsh, 1997). Yield reports for trials all over Europe differ depending on the management and the location; average yields after the 3rd year of establishment without irrigation and with average air temperatures are between 15-25 t DM ha<sup>-1</sup> (Lewandowski *et al.*, 2000).

So far, in most cases no special equipment has been used for harvesting miscanthus but the existing machinery for other crops has been used. Two types of harvesting methods can be distinguished: a) multi-phase using several machines involving mowing followed by swathing, pick-up, compacting and baling and b) single-phase harvest methods using one machine doing mowing followed by chopping, baling, bundling or pelleting in one step, saving labor time (Lewandowski *et al.*, 2000; Venturi *et al.*, 1998). In multi-phase methods, existing machinery for farmers such as forage harvesters used for harvesting silage maize or grass can be used to harvest miscanthus. When mowing and chopping occurs simultaneously to decrease harvest volume, a Kemper "Champion 3000" mowing attachment can be used. In other cases, choppers pulled by tractors have been used but are not preferred by contractors due to low density after chopping which increases transport costs. A way to decrease transport volumes is by making bales in the field. The usual method is to use a swath mower mounted in front of a self-propelled baler. Hesston 4800/4900 and New Holland 4990 big balers can be used for collection and baling according to Kristensen (2003). If whole stems of miscanthus are needed, e.g., for geotextiles or building material, the appropriate method is mowing and bundling.

After harvest, miscanthus has to be stored. If spring harvest has occurred, the crop is stored like dry straw, whereas for winter harvesting, outdoor storage in piles covered with plastic foil is the simplest method (see also reed canary grass).

### 4. WILLOW (*SALIX SPP.*)

Willow plantations, grown as short rotation forestry (SRF), cover about 20000 ha farmland in Europe 2003, and willow wood chips are used for both heat and electricity production. The major part of that area, 15000 ha, is planted in Sweden but willow is also grown in Great Britain (2000 ha), Poland (500 ha), Denmark (> 500 ha), France (150 ha) Germany and Netherlands (100 ha each) and Finland (50 ha ) (Gustav Melin, Agrobränsle AB, Örebro, Sweden, pers. com.). Willow SRF is established with 1.8 10<sup>4</sup> cuttings ha<sup>-1</sup> (1.5 10<sup>4</sup> cuttings ha<sup>-1</sup> if headland is included) in a double row design with alternating inter-row distances of 0.75 m and 1.50 m, and a spacing of 0.50 m between cuttings within rows, adapted to fit the

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machinery. The length of a cutting cycle ranges from 3-5 years depending on stand development. Harvest takes place in winter (November to March) when the shoots have dropped the leaves and the ground is likely to be frozen.

The many different harvest machine concepts that have been tested in willow SRF have been categorised by Spinelli and Kofman (1996):

- *Cut-only harvester.* cuts the stems and leaves them in the field for later collection and chipping.
- *Cut-and-bundle harvester.* cuts and collects the stems in bundles and drop them in the field for later collection and chipping.
- *Cut and-extract harvester.* cuts, collects, loads the stems on a deck and unloads them at the field edge for later chipping.
- *Cut-and-chip harvester.* cuts, collects and chips the stems and loads the chips in containers.

In addition, these harvesters were also categorised as towed or carried by a tractor or being self-propelled, based on the way they are connected to their prime mover.

In Sweden, the development of well adapted harvesters has been going on since 1985 (Danfors, 1992) and all of the above types have been tested. One initial intention when developing the harvesters was to build small scale machines that were not too expensive and that could be attached to a tractor and owned and operated by the farmer himself. This would also have the advantage of supplying work to the farmer during the less labour intensive winter period. However, the development of harvesters (and planting machines) in Sweden took the opposite turn - towards contractor operated large scale machines which proved to be the most cost efficient concept. At the moment nearly all harvest in Swedish willow SRF is carried out by the direct chipping Claas Jaguar forage harvester equipped with a wood cutting header. This harvester cuts two rows at the time and has a maximum throughput of 70 t/h, makes chips that average 34 mm in size, and fills up a lorry with a 100 m<sup>3</sup> loading capacity in 30 min (when running at full capacity). The wood chips are transported directly to the user, the local district heating plant (DHP), and burned fresh without storing and drying. As a consequence of this procedure, one of the major challenges with willow harvest is to make the logistics run smoothly in order to get the harvested crop from the field and delivered to the DHP at a rate adapted to their fuel use. This involves careful planning and, usually, contracts between farmers and users (DHP) are drawn up.

Minimising harvest losses is of importance for the harvest outcome. One factor influencing harvest losses is the stump height. A large proportion of the woody biomass is located in the thick end of the stems, and in the range 10 to 20 cm stump height each cm corresponds to 0.6% - 0.8% of the harvested biomass ( Telenius, 1997 ). For clones with bow-shaped shoots even more of the biomass is located close to soil surface (Verwijst and Nordh, 1992). The recommended harvest level is 5 to 10 cm and consequently it is necessary to keep the plantation free of rocks to avoid mechanical damage on the harvesters.

Stump damage (i.e., split stumps, removed bark) caused by harvesters can negatively affect stool survival, shoot sprouting and, eventually, biomass production (Sennerby-Forsse, 1995). Therefore, harvesters must be designed to make as little stump damage as possible.

Most of the operating willow SRF harvesters are limited by a maximum stem diameter at harvest level of about 60-70 mm. With the present clone selection and a cutting cycle length

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of 3-5 years this stem diameter is seldom reached. But as new, improved and fast growing clones are introduced to the market (Larsson, 1998; Åhman and Larsson, 1999), it may lead to shorter cutting cycles and/or harvester modification.

The development of the harvest technique has led to adaptations of the planting design. Originally, the inter-row distance between double-rows was 125 cm but was increased to 150 cm to fit the harvesters better. This change was necessitated for two reasons. In order to reduce ground pressure and to improve cross-country mobility the harvesters need to be equipped with wide tyres. In addition, the vigorous sprouting of shoots after each harvest makes the stumps wider for each cutting cycle and in the long run this narrows the distance between the double rows.

As the cost of harvest comprises a relatively large part of the overall production cost in SRC, harvest technique improvements have contributed substantially to the economic viability of the several SRCs.

### 5. REFERENCES

- Burvall, J. 1997. Influence of harvest time and soil type on fuel quality in reed canary grass (*Phalaris arundinacea* L.) Biomass and Bioenergy Vol. 12, No. 3: 149-154.
- Burvall, J.; Landström, S. 1997. Vårskördad rörflen – en kommande energigröda. BIOENERGI nr 5. (In Swedish).
- Danfors, B. 1992. Salixodling. Maskiner, arbetsmetoder och ekonomi. Swedish Institute of Agricultural Engineering. Meddelande 436. (In Swedish, English summary).
- Hadders, G.; Olsson, R. 1997. Harvest of grass for combustion in late summer and in spring. Biomass and Bioenergy Vol. 12, No. 3: 171-175.
- Jørgensen U. 2003. Combined production of biomass for energy and clean drinking water – A miscanthus demonstration project on the “Renewable Energy Island” Samsøe. Proc. 1st meeting of IEA-Bioenergy Task 30, Denmark, September 22-25, 2001. In: Jørgensen, U. & Verwijst, T. (eds.), DIAS report - Plant Production 86, 35-40.
- Kristensen, E.F. 2003. Harvesting and handling of miscanthus - Danish experiences 2003. Proc. 1st meeting of IEA-Bioenergy Task 30, Denmark, September 22-25, 2001. In: Jørgensen, U. & Verwijst, T. (eds.), DIAS report - Plant Production 86: 41-46.
- Landström, S.; Lomakka, L.; Andersson, S. 1996. Harvest in spring improves yield and quality of reed canary grass as a bioenergy crop. Biomass and Bioenergy Vol. 11, No. 4: 333-341.
- Larsson, S. 1998. Genetic improvement of willow for short-rotation coppice. Biomass and Bioenergy Vol. 15, No.1: 23-26.
- Lewandowski, I.; Clifton-Brown, J.C.; Scurlock, J.M.O.; Huisman, W. 1999. Miscanthus: European experience with a novel energy crop, Biomass and Bioenergy 19: 209-227.
- Luger E. 1997. Energy crop species in Europe, BLT Weisenburg, Austria.
- Olsson, R. 2003. Production manual for reed canary grass (*Phalaris arundinacea*). Swedish University of Agricultural Sciences. The unit of Biomass Technology and Chemistry. Other publications.
- Pahkala, K. 1998. The timing and stubble height of delayed harvest of reed canary grass grown for energy and fibre use in Finland. In: Eds. H. Kopetz, T. Weber, W. Palz, P. Chartier, G. L. Ferrero. Biomass for Energy and Industry: 10th European Conference and Technology Exhibition; Proceedings of the International Conference, Würzburg, Germany, 8-11 June 1998. Rimpär: C.A.R.M.E.N. Pp. 204-206.

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- Sennerby-Forsse, L. 1995. Inverkan av olika skördeteknik på överlevnad, förnyad skottskjutning och tillväxt hos *Salix*. Slutrapport för projekt nr 927124. Stiftelsen Lantbruksforskning. (In Swedish.)
- Spinelli, R.; Kofman, P. 1996. A review of short-rotation forestry harvesting in Europe. In: Proceedings of the First Conference of the Short Rotation Woody Crops Operations Working Group, Paducah, Kentucky, USA, September 23-25.
- Telenius, B.F. 1997. Implications of vertical distribution and within-stand variation in moisture content for biomass estimation of some willow and hybrid poplar clones. *Scandinavian Journal of Forest Research* 12: 336-339.
- Walsh, M. 1997. *Miscanthus* handbook. Eu project FAIR 3-CT96-1707. Cork, Ireland: Hyperion.
- Venturi, P.; Huisman, W.; Molenaar, J. 1998. Mechanisation and costs of primary production chains for *Miscanthus x giganteus* in The Netherlands, *Journal of Agricultural Engineering Research* 69: 209-215.
- Venturi, P.; Gigler, J.K.; Huisman, W. 1999. Economical and technical comparison between herbaceous (*Miscanthus x giganteus*) and woody energy crops (*Salix viminalis*), *Renewable Energy* 16: 1023-1026.
- Verwijst, T.; Nordh, N.-E. 1992. Non-destructive estimation of biomass of *Salix dasyclados*. *Bioresource Technology* 41: 59-63.
- Åhman, I.; Larsson, S. 1999. Resistensförädling i *Salix* för energiproduktion. *Växtskyddsnotiser* 63: 17-19. Swedish University of Agricultural Sciences. (In Swedish, English summary).

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