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- *Short rotation coppice willow can be harvested from November-April*
- *For small-scale use short rotation coppice willow can be harvested as whole-shoots and chipped after a summer's drying*
- *For large-scale use it is best to harvest as chips and deliver straight away to large consumers*
- *Large-scale harvesting machines should be equipped with tracks, especially on sites prone to ground damage*

Harvesting short rotation coppice willow

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Background

The area of willow short rotation coppice (SRC) in Ireland is expanding in response to new users coming on stream. Willow has the potential to complement and supplement forest-based biomass, given projected increases in demand for woody biomass.

This COFORD Connects Note deals with harvesting of SRC willow only. Other tree species also lend themselves to coppice management: ash, eucalyptus and poplar being good examples. However they are grown on a longer cycle than willow, typically 8-12 years, and are harvested using forest-based machinery rather than the systems used for SRC willow.

Harvesting willow is not as easy as it seems: it is carried out when stems are bare of leaves, from the end of November until April. This also tends to be the wettest period of the year, and given that willow is planted on soils which have a good supply of moisture during the summer, it means that land can be extremely wet during the harvesting period.

There are significant differences in harvesting methods depending on whether one wants to harvest shoots for use in a household boiler or in large-scale boilers. For household consumption only a small area may need to be harvested at any one time, allowing harvesting during dry periods with good ground conditions. Harvesting for large-scale use can involve significant areas of land and the ability to choose dry periods is consequently restricted.

The fuel quality needed for small-scale use is much higher than for larger installations. For small-scale use, well-graded, small-sized chips with a moisture content of 20-30% are needed, while large installations are more or less indifferent to moisture content - although moisture has a large impact on the price per unit volume delivered.

When willow is harvested, the moisture content is around 55-60% (on a wet weight basis), which means that it is difficult to store as chips, and it must be dried for use in small boilers (see COFORD Connects Note on storage and drying of willow SRC).

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A further consideration is the amount of material likely to be harvested. An annual growth rate in the region of 12 tonnes of dry matter per ha, combined with a 2-year harvesting cycle, means that the amount of green wood to be harvested from willow SRC will be about 50 tonnes per ha, comparable to the yield of sugar beet.

Harvesting methods

In general there are three harvesting methods possible for SRC willow:

- whole-shoot harvesting,
- chip harvesting, the so-called cut-and-chip method,
- billet harvesting, the so-called cut-and-billet method.

Whole-shoots and billets will generally have to be chipped at a later stage to be used as a fuel, while material from the cut-and-chip method is ready for use.

Whole-shoot harvesting

In this method there are several ways of harvesting:

- manually, using a bill hook or similar implement
- motor-manually, using a chainsaw or brush cutter
- using tractor-drawn equipment or
- self-propelled machines.

Obviously the first two approaches are suited for small areas only, where fuel is harvested for household consumption. Tractor-drawn equipment can be used on larger areas of coppice, while self-propelled machines are best suited to very large blocks. Some tractor-drawn machines collect shoots on a loading bay (Figure 1); others bundle the shoots to ease transportation and subsequent handling. Some machines transport the shoots to the landing themselves, while others unload directly onto the field. For both systems shoots need to be stacked for better drying. Even those machines that transport shoots to the landing cannot pile them to any appreciable height, so there is a need for additional piling.

The purpose of harvesting whole-shoots is to let them dry naturally in as high a pile as possible at the edge of the field. This requires a fairly large landing area. After a summer's drying, the shoots are chipped before being used as fuel. Chipping of whole-shoots is difficult, since drying makes them brittle and moving them to the chipper by crane can break many of them. Also, small side-twigs break off easily during handling and a large pile of debris can be left behind after chipping. This method of harvesting is recommended for small areas only, where the wood is going to be used on the farm or otherwise close-by and in small amounts.

Figure 1: Frobesta whole-shoot harvester drawn by tractor.

The quality of willow fuel is critically dependent on the type of chipper used to convert shoots to chip. The machine should be in perfect condition, with sharp knives, a sharp anvil and properly adjusted infeed speed. The distance between knife and anvil should be less than 1 mm. If the machine can be equipped with a screen, then a small mesh size should be used. With careful in-feed of shoots, a nice quality wood chip can be produced, but if machine parts, such as blades, are not properly maintained, poor quality, irregular chips will be produced, which may lead to blockage of boiler in-feed augers, and uneven combustion.

Cut-and-chip

In the cut-and-chip method there are two main ways of harvesting:

- tractor-mounted equipment and
- self-propelled machines.

Tractor-mounted equipment is cheaper and has a lower weight than self-propelled machines, but has a lower productivity. (see Figure 2).

Many self-propelled machines are derived from agricultural machinery, such as silage harvesters or come from the sugarcane industry. They are equipped with a different cutting header, as woody plants are much harder on cutting equipment than grass or sugarcane. A cut-and-chip machine can either

Figure 2: JF tractor pulled double row willow harvester.

pull its own trailer to collect the harvested material or use a tractor-trailer combination, which travels alongside the harvester and receives the chips (see Figure 3).

Self-propelled machines tend to be much heavier than tractor-mounted harvesters. This can pose problems on soft terrain, where machines compress and compact the top soil and lose traction. A solution is to replace wheels with caterpillar tracks. The disadvantage of a tracked vehicle is that it has to be transported on a low loader to the next site. If tracks are used the trailer and/or a tractor trailer-combination used to receive chip should also be tracked.

As pointed out, these harvesting methods are best suited to large sized areas, where the large capacity of the machines can be fully utilized and their high capital cost can be spread over large harvest volumes.

Chips produced using cut-and-chip methods are very wet and have a high level of plant nutrients in the bark, so they are unsuited for long term storage. Within a few days high temperatures (around 80° C) will develop in chip piles with subsequent losses of dry matter and a risk of spontaneous combustion in very large piles. As a consequence, chips need

Figure 3: A Claas silage harvester blowing chips into a tractor trailer unit.

to be either put into a drier or transported straight away to a consumer to be burned within days of production.

Cut-and-chip machines have a high productivity, with large volumes of fuel produced over short periods, which needs to be quickly unloaded into containers for road transportation. This reduces the need to store chips on the ground, and the probability of soil contamination. If piles are needed they are usually located near the field exit, preferably adjacent to a road. Storage areas tend to be heavily trafficked, so their location should be carefully chosen to avoid wet areas which can quickly become extremely muddy, leading to chips being contaminated by soil.

As cut-and-chip methods can produce a truck-load of chips per hour (around 25 tonnes), logistics are very important. At the fuel receiving end, the customer needs to make provision for efficient off-loading and rapid turn-around of haulage vehicles, so as to keep a tight rein on costs.

The quality of wood fuel from adapted silage harvesters is normally very high; cut-and-chip machines make a nice, even-sized chip with very few overlong particles. Those that may arise are mainly from thin side twigs, and will pose little or no problem for the boiler infeed.

Cut-and-billet

Machines derived from sugarcane harvesters, such as the Austoft, are also used for harvesting willow coppice, using a cut-and-billet system. They are capable of producing much coarser chips or even chunks. The normal setting of the machine produces 5 cm chips, but by removing some of the knives and lowering the drum speed, 10 cm chip or even 20 cm billets can be produced (see Figure 4).

Figure 4: Austoft self propelled harvester unloading into tractor-trailer combination.

The advantage of the larger particle size is that the material is easier to store and dry, because the piles are much more open to natural ventilation. On the other hand, the fuel is generally not suited for small-scale boilers. The 20 cm billets have to be re-chipped before they can be used as fuel. The 10 cm wood chip could perhaps be used in large installations, if they are able to handle such fuel.

Synoptic comparison of willow SRC harvesting methods

Some words of warning

Normal agricultural machinery is not built to cope with the strain of harvesting short rotation coppice. Woody material is much tougher on machines than grass or maize. Attempts have been made all over Europe to harvest SRC with un-adapted silage harvesters, but generally the machines fail within days, as the header is not strong enough for cutting stool shoots.

The cutting mechanism of silage harvesters should be adapted when used on SRC. In many cases at least half the knives are removed to reduce the strain on the cutting drum, resulting in a slightly longer chip. Harvesting SRC is very hard on the knife drum bearings, which need to be greased and inspected much more frequently than when in normal agricultural use. It must also be borne in mind that the special headers used for harvesting willow coppice need a much higher rate of hydraulic oil flow, so larger pumps and oil cooling systems will have to be installed.

Attention should also be paid to tyres, as SRC coppice stools, especially after a few harvests, are far more aggressive than maize stalks. Often machines are equipped with forest-based machinery tyres, which have tougher side walls.

Table 1: A qualitative and quantitative comparison of the operation and output of whole-shoot, cut-and-chip and cut-and-billet methods for harvesting SRC willow.

Factor/method	Whole-shoot	Cut-and-chip	Cut-and-billet 20 cm
Area			
Small < 1 ha	++	—	—
Medium < 5 ha	+	+	+
Large > 5 ha	—	++	++
Cost			
Small < 1 ha	+	—	—
Medium < 5 ha	—	+	+
Large > 5 ha	— —	++	++
Harvesting Productivity, tonnes/hr			
Small < 1 ha	< 5	< 10	< 10
Medium < 5 ha	< 10	< 25	< 20
Large > 5 ha	< 10	< 25	< 20
Logistics			
Small < 1 ha	simple	medium	medium
Medium < 5 ha	medium	high	high
Large > 5 ha	high	very high	very high
Drying possibility			
Small < 1 ha	++	+	++
Medium < 5 ha	++	—	+
Large > 5 ha	++	— —	+
Conversion to fuel	costly	not needed	costly
Markets	small consumers	large consumers	small and medium
Investment	low	high	high

Legend: very good ++, good +, poor—, bad——

Summary and conclusions

Not all harvesting methods are suited for every set of circumstances. For small-scale usage, the whole-shoot method is probably best. Only a limited area needs to be felled and the shoots dry very well over a summer in a stack. Alternatively for small-scale use, the cut-and-chip method can be used but drying chip is not easy and can be very expensive. The cut-and-billet method can also be used because billets dry a lot easier than chip. However, as pointed out, billets generally have to be re-chipped before use as a fuel.

For large scale use the cut-and chip is the cheapest way of harvesting willow SRC, but the system entails good planning and logistics.

During wet periods and on soft ground machines and trailers should preferably be equipped with tracks.

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