



Harvesting

Timing

Willows should be ready for first harvest three years after coppice (four years after planting). If growth was poor due to weed competition, pests, drought, or other factors, harvesting may be delayed one year or more. Waiting longer than four years of normal growth to harvest is not recommended, as growth rates will begin to decline, and large-diameter stems can damage equipment and make operations less efficient. Harvesting is ideally completed during the dormant season after leaf-fall (Figure 1) and before bud-swell. Optimal conditions for harvesting are frozen ground and little or no snow, but these conditions may not coincide with the planned harvests and equipment availability. Willow can be harvested with leaf-on, but the moisture and ash content of the chips may increase, and nutrients in the leaf will be removed from the site instead of being recycled into the soil. Stem regrowth after harvest that does not harden off before leaf-fall will likely die over winter. This expends some of the plant's stored energy and nutrient reserves, and hinders the plant's ability to compete with weeds the following spring.



Figure 1: Shrub willow is ideally harvested after leaf-fall with frozen ground and little or no snow.

Machinery

The harvesting system that has been used for commercial acreage in the U.S. is a New Holland FR 9000 series or Forage Cruiser series forage harvester, equipped with a FB130 woody-crops cutting header (Figure 2). This machinery was developed by New Holland in partnership with SUNY-ESF and has proven effective in harvesting commercial-scale acreage. The system is most efficient on larger fields and parcels of land in close proximity to one another. This machinery is available from New Holland dealerships, and for rent or custom jobs from Celtic Energy Farm (www.celticenergyfarm.com). A tractor-mounted harvester for smaller willow stems and smaller acreages is available for rental or custom jobs from Double A Willow (www.doubleawillow.com). Tractors and wagons or trucks follow beside the harvester to collect chips.



Figure 2: Harvesting shrub willow with a New Holland FR Forage harvester and FB130 woody crops cutting header.

Two or three wagons/trucks are generally needed to maintain efficiencies and avoid harvester downtime, depending on the capacity of the wagons/trucks and the distance to the unloading spot. The type of wagons/trucks used may depend on what is locally available, but silage trucks or large capacity dump wagons, both with heavy-ply tires, are preferred. Silage trucks with flotation tires in the rear have been effective. A skilled operator with experience using the New Holland system to cut woody energy crops should be involved in the process. More information about the specifications of New Holland harvesting equipment is available from the Penn State fact sheet *Willow Harvesting Equipment Considerations* available at www.esf.edu/willow.



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Operations

Shrub willow is planted at high density in a double-row pattern and produces numerous woody stems per plant (see *Planting* fact sheet). Plants have a ground-level branching pattern (Figure 3) with an upright or arching stem form. Plants can grow to a height of about 20 to 25 feet or more before harvest. Individual cultivars have different growth forms, stem diameters and numbers of stems per plant, which will affect the ease and logistics of harvester operation. Woody crops are larger and denser than herbaceous crops such as grasses or corn, so care must be taken during willow harvests to avoid damage to machinery. Willow stems should not be allowed to grow beyond three to four years after coppice/harvest to avoid overgrown stems that exceed the mechanical specifications of the harvesting machinery.



Figure 3: Shrub willow has numerous stems per plant that are cut near ground level and re-sprout from the remaining stool in spring.

The New Holland harvesting system cuts and chips willow stems in one pass. An adjustable bar bends the willow stems forward to help feed them into the header. Rotating saw blades at the bottom of the header cut the willow stems near the base of the plant, and two sets of rollers feed cut stems into the forage harvester. Stems are chipped by knives inside the forage harvester and exit through the spout into wagons/trucks. Optimal efficiencies are achieved when harvester downtime is minimized. Factors affecting harvester downtime, material throughput and overall efficiency include the number and capacity of wagons/trucks, field layout, adequate headlands for turning at the end of rows, ground conditions, crop resistance, harvester operator, breakdowns and flat tires. Each site should be assessed to create a harvesting plan based on these factors.



Figure 4: Dumping a load of willow chips onto a large pile for short-term storage before reloading and transport to an end user.

Chip Storage, Loading and Hauling

Harvested chips are typically transported to the edge of the field or nearby landing by wagons/trucks and dumped directly into a large truck for road transport to an end user, or dumped in a short-term storage pile (figure 4). Chips loaded directly into silage trucks can be delivered a short distance to an end user or storage location, but this will increase the number of collection vehicles needed to keep avoid harvester downtime. Short-term storage piles are typically loaded into trucks using a high-dump attachment for a loader or

similar machinery. Each acre of mature willow will produce about one semitrailer load of chips at harvest, weighing around 25 tons, so it is important to have a landing area that can accommodate short-term storage.



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Safety

There are numerous safety protocols for agricultural operations in general, and additional protocols for dedicated energy crops that are often harvested in winter conditions. Key safety points to consider for willow harvesting are listed below. This is *not* a comprehensive list of safety protocols for biomass harvesting. For complete information, consult the Penn State University *Safety and Health Management Planning for Biomass Producers* guidebook available at www.esf.edu/willow.

- Before harvest season, check that equipment cab heaters and window defrosters are working.
- Allow extra time to harvest. With shorter and cooler day lengths, it takes longer for wet ground to dry if it does not freeze.
- Be certain that reflectors, flashers and lights on equipment are clean and operational. With shorter days it is more likely that equipment will be on roadways when daylight is not optimal.
- Ends of cut willow stools are sharp; be sure of footing near cut stools to avoid falling on them, and take necessary precautions to extend tire life when operating in these fields of willow.
- When operating on frozen ground, remember that snow may be covering patches of ice. This is especially important on slopes.



Figure 5: Aerial photo of a shrub-willow harvest in progress

More Information

More information about willow harvesting equipment, process, costs, and chip quality is available in a series of research summaries and related fact sheets available on the ESF willow publications page (<http://www.esf.edu/willow/pubs.htm>), or contact us by phone or email using the information below.

The Willow Project at SUNY-ESF

www.esf.edu/willow | (315) 470-6775 | willow@esf.edu

Northeast Woody/Warm-Season Biomass Consortium

www.newbio.psu.edu

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