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Mechanized harvesting of one year old willow and poplar crops for producing planting material

The growing demand for willow and poplar planting material in Europe concurrent with rising cost pressure for producers has resulted in new challenges for the industry. The main subject of this European Union funded research project is to develop an efficient technology for mechanical harvest and preparation of planting material. The following article is focused on the development of the harvesting techno-logy “ROD-Picker” and the presentation of the cost saving potential concerning harvest and production costs.

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Abstract
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Until 2020, the European wood demand will exceed the domestic availability by far [1]. This development is intensified by rising fossil fuel prices and legal requirements of the EU member states concerning the minimum renewable energy share in total energy consumption. Between 2000 and 2013 Germany’s firewood consumption already rose by 200 % to around 75 million m³/a [2]. By substituting other traditional raw materials and basic chemicals with wood products, the demand will continue to increase in the future. Due to relatively high additional transport and handling costs the biomass import from overseas is basically only for a few large scale consumers near the coast of economic interest.

For a fast and environmentally responsible production of the required biomass the cultivation of agricultural wood in short rotation plantations gains in importance. Besides, this production also strengthens regional value chains. In Central and Northern Europe, mainly poplar and willow are grown on agricultural land. Based on the increase in area since 2010 in the EU, an overall plantation area of about 150,000 ha could be extrapolated for the year 2020. To meet the respective planting material demand, about 1,200 ha of tree nurseries must be harvested on average each year. Hence, an efficient harvesting technology needs to be development.

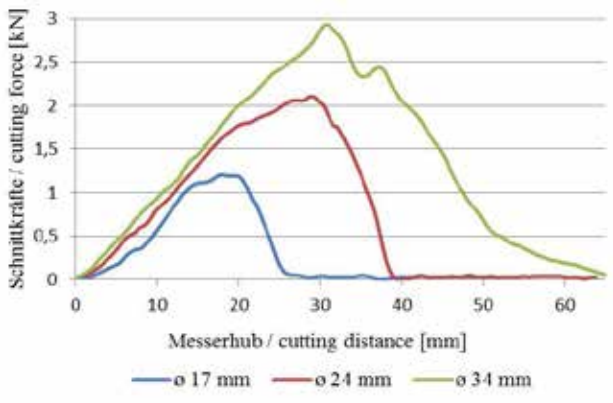
Harvest of raw material and preparation of planting material

To maximize the planting material yield many nurseries for short rotation plantation are created with a row spacing of 50 to 75 cm [3]. However, plantations with a row spacing of up to 2 m are also usual in practice. This allows farmers to flexibly adapt rotation periods and thus to produce energy wood as well, e. g. in times of declining planting material demand. The harvest of one year old poplar and willow rods are executed exclusively during the winter months and is currently characterized by a very low degree of mechanization. In addition to manual harvesting with brush saws, older pre-series or self-constructed harvesting machines with low efficiencies are sporadically in use. A market study revealed that no production-ready harvesting machines are commercially available. Subsequent processing of the harvested rods usually takes place in a hall. After manual sorting and separation of waste material, the rods are cut to a length of up to 2.40 m and packed in bundles of 50 pieces or they are further processed into 200 mm long cuttings. The high share of manual labor during harvest and further processing means that about 60 % of the establishment costs of a new plantation are attributed to the planting material (10,000 pcs / ha, 0.19 €/pcs, variety Max 3) [4]. Only by mechanizing individual steps of the process chain an increase in acreage capacity with a simultaneous reduction in costs can be achieved.

Mechanization of planting material harvest

A survey among operators of short rotation plantations conducted at project start showed that harvest rates should be increased and non-productive time, e. g. by unloading, should be minimized. Along with performance and reliability a sensitive gathering and transportation of the susceptible rods are the most important requirements for developing a harvesting machine. Already smaller bark injuries may adversely affect

Fig. 1



Test stand with cutting distance (left), cutting forces of a cutting bar with fresh poplar rods (right) (Photo: Peschel, TU Dresden)

the tree's sprouting and lead to total failure. Hence, feeder belts specifically developed for this purpose are used for fixation and transport of the rods. The harvest speed is significantly influenced by the permissible feed rate of the cutting unit. Therefore, different cutting principles were examined in test rigs regarding their suitability.

The measurements indicate that saw blades are best suited for severing rods from the rootstock. The feed rate and thus the speed of the harvester could be increased with minimal effort by raising the input speed. However, for capping free branches or shoot tips saw blades are of limited suitability due to the lacking abutment. If the cutting diameter is less than 30 mm, fast running cutter knife bars as those being used by municipal services could be applied for cutting off shoots at a speed of up to 7 km/h. These bars pinch the wood between fingers and knife, enabling a clean cut.

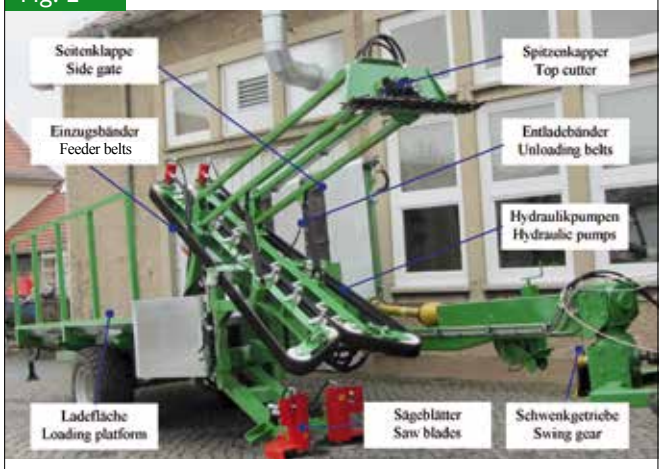
Figure 1 displays the average cutting forces recorded during the experiment for severing fresh poplar rods with different diameters. The distance between the fixed counter-blades is 60 mm. For designing the drive of the cutting bar the maximum occurring cutting force of 3 kN is multiplied by the number of shoots per rootstock. The harvester prototype is equipped with fast rotating saw blades for separating the rods from the rootstocks and a cutting bar for severing the shoot tips of the rods.

ROD-Picker – prototype

As part of a research project at the Technische Universität Dresden, the ROD-Picker prototype was developed (**Figure 2** and **Table 1**). As a fully hydraulic working machine the ROD-Picker is driven by the tractor PTO shaft and requires a maximum power output of 35 kW. Barring the pivoting cylinder of the draw bar, all working units are supplied by the four hydraulic pumps installed on the machine. All functions are conveniently controlled by an operation terminal.

The rods are fixed by the feeder belts at first and subsequently severed from the rootstock by using the saw blades. The speed of the feeder belts can be adjusted continuously variable and independently from the harvesting speed. After the cut, the rods are transported by the feeder belts to the loading floor. Due to their pretension the rods fall independently into a horizontal position. Depending on the variety and tree height, the loading

Fig. 2



ROD Picker prototype (Photo: Peschel, TU Dresden)

Table 1

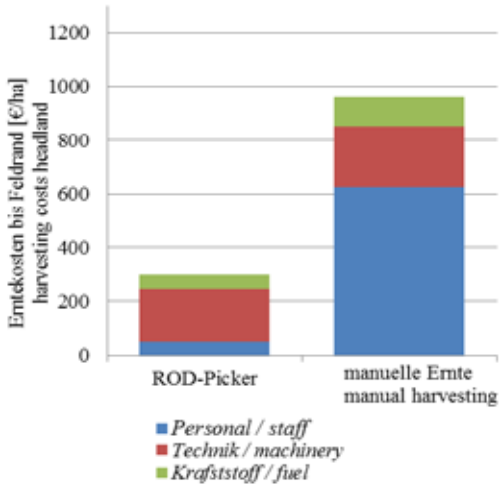
Technical data

Abmessung L x B x H *Dimension L x W x H*	7 060 x 2 520 x 2 500 mm
Gewicht leer *Weight empty*	2 900 kg
Traktorleistung *Power required*	min. 60 kW
Zuladung *Payload*	1 500 kg
Erntegeschwindigkeit *Harvesting speed*	max. 12 km/h
Schnittdurchmesser *Cutting capacity*	max. 80 mm

Fig. 3

Saw blades and feeder belts (left), unloaded poplar rods (right) (Photos: Peschel, TU Dresden)

Fig. 4



Comparison of harvesting costs by manual harvest with brush cutter and by using the ROD-Picker

capacity of the harvester accommodates the yield of up to 700 m of willow rows (planting distance 30 cm, single row).

The loading platform as well as the folding site gate are equipped with belts glued with rubber tangs which allow to transfer the material on a trailer driving alongside. This reduces downtime of driving to the unloading site. Alternatively, the rods could be unloaded conveniently on the headlands via the belts. For harvesting higher stands the entire harvest unit is extend by up to 300 mm. The top cutter severs the shoot tips, which may not be suitable for planting material production. Thus, the machine already executes one step of the subsequent planting material processing on the field. The cutting height is adjustable from 2.20 to 3.50 m and could be adapted to different tree heights also while driving.

Table 2

Main data for calculating the harvesting costs

	ROD-Picker	Manuelle Ernte *Manual harvest*
Ernteleistung *Harvest performance*	4 000 m/h[1)]	500 m/h[1)]
ROD-Picker	30 €/h[1)]	-
Freischneider *Brush cutter*	-	6 €/h[4)]
Transportanhänger *Trailer*	-	8 €/h[1)]
Traktor/*Tractor*	29 €/h[2)][5]	18 €/h[3)][5]
Dieselverbrauch *Fuel consumption*	12 l/h[1)]	6 l/h[1)]
Personalbedarf *Staff requirement*	1 AK	3 AK
Personalkosten *Labour costs*	15 €/h	10 €/h

[1)] Eigene Datenaufnahme und Berechnung/*Own data recording and calculation.*
[2)] Traktor mit 84 bis 102 kW bei 75 % Auslastung/*Tractor power 84 to 102 kW at 75 % utilization.*
[3)] Traktor mit 55 bis 67 kW bei 75 % Auslastung/*Tractor power 55 to 67 kW at 75 % utilization.*
[4)] Kosten für Freischneider inkl. Kraftstoff, eigene Datenaufnahme/*Costs for brush saw including fuel, own data recording.*

Experimental results

In the first operations (**Figure 3**) between January and March 2014 around 18 ha of willow (Sven, Tordis, Inger, Tora) and poplar nurseries (Max 1-4, Hybride 275, Matrix 24) have been harvested. On average, the machine reached a harvesting speed of 6.5 km/h. During trials without the top cutter unit mounted, harvest speeds of more than 12 km/h were reached. These high speeds were only realized briefly by the tractor driver, as the machine is operated manually at present. An average row length of 400 m could be harvested without unloading in one year old nurseries.

Using the example of a nursery with a row spacing of 75 cm, a row length of 400 m and a planting density of 37,700 pcs/ha the costs for manual harvest with brush saws and the mechanical harvest with the ROD-Picker are calculated (**Table 2**). The calculation is based on the time measurements and other data recorded during the test trials. In that case, the harvested material was unloaded by the ROD-Picker on the headlands. Further planting material processing is not included in the calculation. As a result, the total costs (**Figure 4**) for manual harvesting exceed mechanical harvesting by factor 3. While the ROD-Picker could be operated by one worker, at least three worker are needed for the harvest with brush saws – with a significantly lower acreage capacity. In combination with the stationary unit for further processing of the rods, the production costs of prepared planting material can be reduced by up to 30 % with a simultaneous increase in production capacity.

Conclusions

The results and measurements recorded during the first harvest operations are integrated in the further development of the ROD-Picker prototype. The goal of the project is the construction and manufacturing of a pre-series machine, which will be applied in long term tests by the industry partners during the next harvesting season in 2014/15. Having successfully completed the testing phase, the Danish company EGEDAL is in charge for the gradual market launch and commercial production of the ROD-Picker.

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Remarks

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