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Examination of bark content for different species of short rotation coppice

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Abstract. Short rotation coppices (SRC) can produce large amount of dendromass in a short time. From an energetic point of view, one of the most important challenges are the outstanding amount of ash content, which is primarily generated due to the high bark content of the thin shoots. Our research was carried out for measuring bark content of four species/clones performed in three different vegetation years. The experimental plantation is located in the northwestern part of Hungary. The results show that the bark content strongly depends on the applied harvest frequency and tree species. Based on the measurements, the Robinia pseudoacacia and the Salix alba species have the largest bark content in the first year but the value can be reduced by around 50% by using longer harvest rotation. Having analyzed the whole stem, the bark percentage of the Populus x euramericana clones increased from 5.5% to 33.7% from the cutting height to the tip. The minimum value was at the diameter class of 24-28 mm. In the case of Robinia pseudoacacia the bark content ranges only between 3.0% and 20.0%.

1. Introduction

The EU targets for renewable energy have been increasingly strengthened. The 2009/28 EC (Renewable Energy Directive) requires to fulfill at least 20% of the total energy needs with renewables by 2020. As part of its Clean Energy for All Europeans package, the European Commission proposed an update of the Renewable Energy Directive for the period 2021-2030 in 2016. The final version of RED II raises the overall EU target for renewable energy sources (RES) by 2030 to 32%. Biomass has an important role in achieving the goals.

Forest residues as free biomass potential have become increasingly important in energy production; however, collecting them is a serious cost factor. Agricultural by-products, such as straw, can be part of the animal feed mix and therefore can be indirectly linked to the food chain [1]. Furthermore, the organic carbon content of the soil is adversely affected by the large extraction of straw from the agricultural area [2]. The growing need of lignocellulose feedstock based energy production can only be met with cultivated woody plants, together with the limited collectable and useable by-products [3]. The growth of SRC has a positive impact on soil ecology, which can be detected in eroded places within 3-5 years [4-5]. Compared to the conventional agricultural crop production, the growth of woody plantation results in increasing the amount of organic matter into the soil, which improves the nutrient uptake and removes the carbon from the atmosphere. Furthermore, SRC can achieve a satisfactory yield in low quality agricultural areas after choosing applicable tree species and careful soil preparation [6].

From an energetic point of view, four properties of the woody biomass are decisive during the utilization: the density, the calorific value, the moisture content and the amount of ash and its components [7]. The average ash content is less than 1% for debarked wood, 1.5-3.5% for the wood in bark, and 2.0-4.0% for wood branches (forest residues) [8]. In the case of poplar SRC, the ash content is higher, the value varies from 0.9% to 3.2% [10], while for bark can reach to 14% [9]. The ash content is primarily determined by bark content whose value on the whole steam ranges between 10-27% [11-12]. The high ash content can cause problems on the wall of the combustion furnace, while the increased ash content results in a larger amount of particle emissions and firing by-products. Therefore, it is an important task to reduce the ash content by selecting and pretreating of the base material as well as by applying farming technology [13].

The K and Si content of the produced ash is lower, while the Ca and Mg content is higher during utilization of woody plantation than herbaceous materials [10]. It is the main reason why it is more favorable to fire dendromass from SRC, as opposed to agricultural by-products. The lignin content of bark is higher than debarked wood, which results in higher calorific value [14]. At the same time, the moisture content of the bark is about 20-25% more than in the case of the debarked wood, so it does not give an advantage from an energetic point of view under real conditions [15].

SRC can also play a role in the production of liquefied biofuels, according to the latest technologies. In particular, it is projected that the diesel engine will be expected to remain on the road for a long time [16]. However, the high bark content of SRC reduces the bio-oil yield and increases the instability of the product due to the substantial alkaline and alkaline earth content [17]. Mészáros et al. (2004) analyzed young shoots (poplar, willow, robinia) from SRC with thermogravimetric/mass spectrometry method and compared the thermal decomposition characteristics of wood and bark [18]. Based on their measures, the mineral content of the bark is significantly higher than the wood. The thermal conductivity of wood and the bark was still significantly different after using the washing process as pretreatment but their macromolecular components decomposed at similar temperatures. Frankó et al. (2015) investigated the effect of bark on the ethanol production and found that it affects the bioconversion process due to the less enzymatic hydrolysis capability, which can be improved by pretreatment [19].

2. Materials and methods

2.1 Description of the experimental site and plant material

The measurements were completed in December 2013 on the Bajti Experimental Plantation of the Forest Research Institute (NAIK ERTI) in Hungary. The plantation was installed in April 2007. The planting scheme is a simple row design with 0.40 m plant spacing and 3.00 m row spacing. One parcel contains 65 rows with different clones in each row. The plantation was completed in three repetitions and cultivated with a coppicing technology.

During the winter of 2007/2008, the area suffered wild game damage; thus, at the beginning of the year 2008, the second and third repetitions were cut before the planned time. From here onward, another parcel will be harvested each year with a three-year cutting-cycle. The advantage of the plantation is that several species and clones are present in the area in the first, second, and third vegetation year under the same soil and climatic conditions; see Figure 1. This experiment gives us an excellent opportunity to compare the energetic characteristics of different species and clones.

The test area is a claylay loam forest soil in hornbeam-oak climate in medium deep topsoil, which is independent from extra water. Nutrient replenishment during the cultivation or watering after planting is not used.

Figure 1. The plants in the experimental plantation in the first, second and third vegetation year.

For the investigation, we have selected the species/clones with the highest yield in the area. The other aspect was the examination of the most widely used clones in Hungary.

The analysed species/clones are the following:
- Populus x euramericana ’Koltay’
- Populus x euramericana ’I-214’
- Salix alba ’Drávamenti’
- Robinia pseudoacacia

2.2 Measurements
The sampling was carried out in December 2013 when the time of actual harvesting was due because the moisture content of the stems is the lowest in this period. It gets us a realistic state for the ratio of bark and wood. From each of the four tree species/clones, an average-sized stems were cut at the age of three. Every 50 centimeter from the shoot with approx. 1 cm wide section was sampled, see figure 2

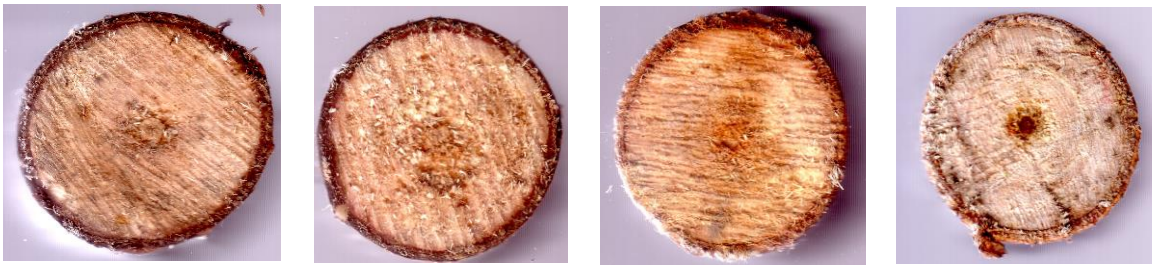

Figure 2. Samples (Populus x eur. ’Koltay’; Populus x eur. ’I-214’; Salix alba ’Drávamenti’; Robinia pseudoa.).

Afterwards, the bark was removed from the wood by using a peeler knife and the absolute dry matter was weighed separately. The bark percentage for the different diameters can be obtained by using the equation below

$$bark_{w\%} = \frac{w_b}{w_{bw}} * 100 \qquad [\%] \qquad (1)$$

where
bark w% - bark percentage for dry matter
w_b -weight of bark for dry matter
w_{bw} - weight of wood in bark for dry matter

The data was classified according to the diameter. The resulting values were applied to the shoots harvested in the summer of 2013 at three different vegetation years. This method resulted in a high number of elements. In all cases, we summed the weight of the bark and debarked wood, from the cutting height to the tip. It was followed by the calculation of the bark percentage for the whole shoots, then for the whole plant and for one hectare.

3. Result and discussion

3.1. Bark percentage in the first, second and third vegetation year

Based on the measurements, we determined the bark percentage for the four species/clones in different vegetation years. The highest bark percentage was typically obtained in the first vegetation year when the diameter of the stems is still small. Their average value ranged from 12 to 18%. In later years the bark percentage depended on the specific growth rate of species/clones. The difference of the bark percentage in the 2nd and 3rd vegetation year is only significant in the case of Salix thanks to the intensive shoot growth in the third vegetation year, see figure 3.

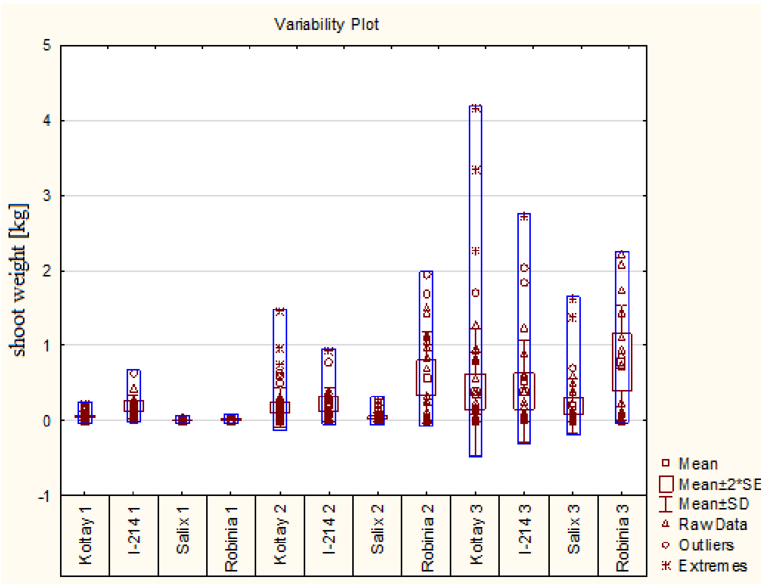

Figure 3. Shoot weight distribution of the four species/clones in three vegetation years.

Robinia had the smallest bark percentage, slightly more than 6%, while Populus clones have about twice as much. Fig. 4 demonstrates the values for the different vegetation years, which refer to the absolute dry weight.

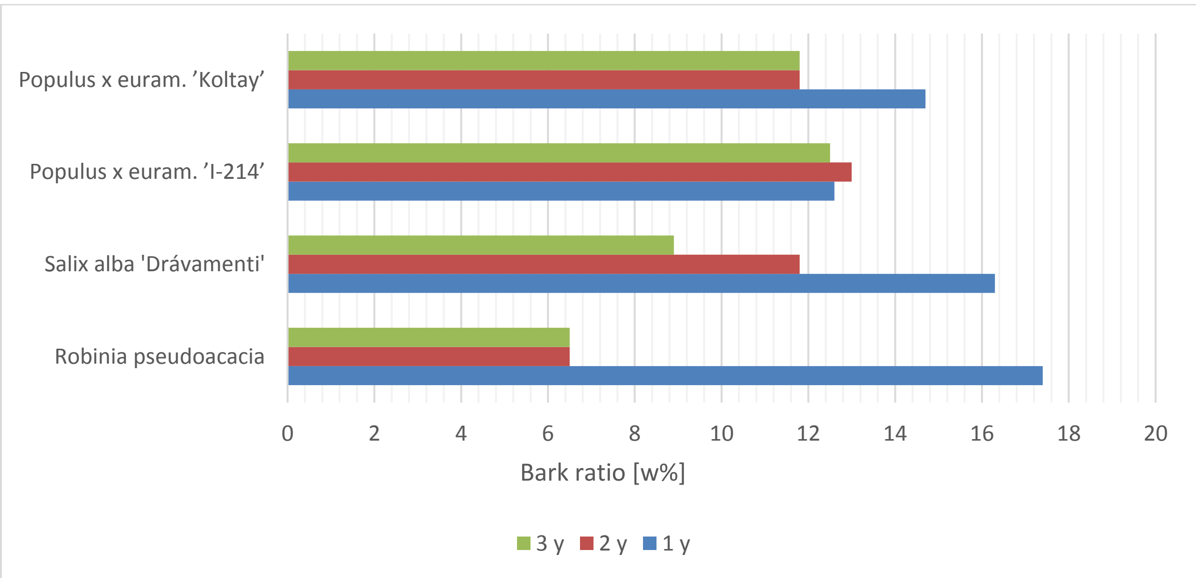

Figure 4. Average bark percentage of investigated species/clones in different vegetation years.

3.2. Bark percentage for different diameter classes
A relationship between diameter and bark content was established and the values were classified. The bark content mostly changed in the case of poplar clones from nearly 5% to 33% from the cutting height to the tip. In the case of willow and black locust the value was lower, it ranged between 3-20%. Generally, the bark percentage decreased rapidly in the small diametric classes up to 25 mm, then we observed a slight increase, see figure 5.

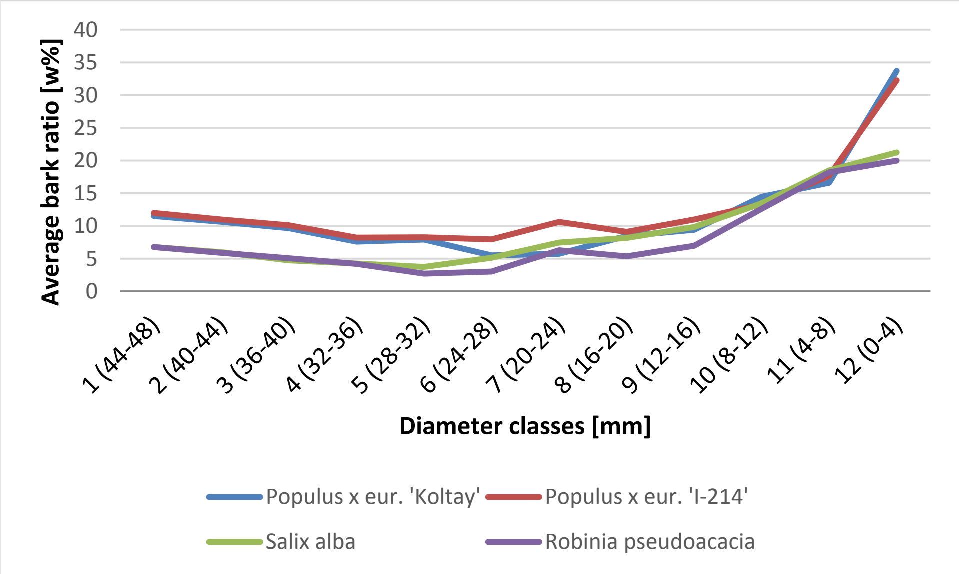

Figure 5. Average bark percentage in the different diameter classes.

4. Conclusion

The short rotation coppices can play an important role to meet the growing energy demand in the future. The dendromass can be widely utilized in applications like district heating, power generation, alone or in combination with other fossil fuels or biofuel production as well. Usability of the woody biomass is largely influenced by the ash content, which is primarily determined by the amount of the bark. The results of the experiment provide an estimate for the bark percentage facilitating the selection of the suitable energy production technology. The bark percentage was given for different diameter classes, and its change of the total bark content within the whole stem. The experiment provides an opportunity for further estimates of bark content by measuring the diameter of the stems in the case of the same species/clones. Furthermore, it can be concluded that the bark percentage of Robinia psudoacacia and Salix alba can be reduced by around 50% by selecting the appropriate harvest rotation.

5. Acknowledgement
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