ENERGY PRODUCTION FROM SHORT ROTATION POPLAR PLANTATIONS

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Abstract:

The objective of this work was to estimate the dry matter production and energy potential of 6 poplar clones (P.x euramericana cl. Ostia, P.nigra cl.53/86, P deltoides cl. PE 19/66, P.x .euramericana cl.I-214, P.x deltoides cl. S6-7, P.x euramericana cv. Robusta), with two different plant densities (38461 plant/ha and 83333 plant/ha) aged one year rooted cuttings. Average dry matter biomass yields reached 21 t ha^{-1} year^{-1} (38461 plant/ha), and 12 t ha^{-1} year^{-1} (83333 plant/ha). Based on calorific values of oven dry wood and bark of each clone, average energy potential of researched poplar clones was estimated up to 395 GJ ha^{-1} year^{-1}, and for denser plantation up to 222 GJ ha^{-1} year^{-1}.

Key words:

Poplar clones, biomass production, biomass characteristics, combustion.

1. INTRODUCTION

Shortage of wood in general, especially in last decades, has led to excessive exploitation of forest resources. Intensive cultivation of fast growing forest species on short rotations can solve this problem, especially in those regions where there are large areas suitable for poplar and willow growing. Biomass is considered to be one of the key renewable resources of the future at both small and large scale levels. It already supplies 14% of the world's primary energy consumption. On average, biomass produces 38% of the primary energy in developing countries (90% in some countries). Biomass is likely to remain an important global source in developing countries [5]. Even in developed countries, biomass is being increasingly used. A number of developed countries use this source quite substantially. e.g. in Sweden and Austria 15% of their primary energy consumption is covered by biomass. Sweden has plans to increase further use of biomass as it phases down nuclear and fossil fuel plants [17,1].

Plantations help ease shortage of forestry wood. In 1995 the industrial plantation area was estimated to be 103 million ha and the non–industrial plantation area to be 20 million ha [14]. Over 50% of the plantations are assessed to be less than 15 years and 25% are less than five years [2,18]. The establishment of new plantations is assumed to increase between 160 and 235 million ha in year 2050 [18]. Thus, the above-indentified regional and global shortages of wood supply would be much worse without the establishment of plantations.

Short rotation intensive culture or tree biomass cropping refers to woody biomass production in carefully tended plantations using fast growing hardwoods of good coppicing abilty, for rotations of less than 15 years [6]. Management objectives centre on maximising annual woody biomass yield per unit area. The success of the biomass production concept depends, in part, on the efficient production systems. Agricultural management practices (plant spacing, high density, use of herbicides, short rotation and regular harvests) are applied to fast growing tree species (such as hybrid poplar, willow or eucalyptus). Poplar appears to be a model species and prototype for such tree biomass plantations. The idea of producing large amounts of wooden biomass by cultivation of fast growing tree species with different rotation periods is a well known approach [12,13,3,14,15].

The objective of this work was to estimate the dry matter production and energy potential of six poplar clones with two different plant density (38461 and 83333 plant/ha) aged one year rooted cuttings. Interclonal differences of the poplar clone potential for biomass yield were determined based on the study of plantations with a high number of seedlings per unit area.

2. MATERIAL AND METHOD

An experimental field plantations were established in experiment estate “Kacka suma”. In the field trial 6 poplar clones (*P.x euramericana* cl. Ostia, *P.nigra* cl.53/86, *P deltoides* cl. PE 19/66, *P.x .euramericana* cl.I-214, *P.x euramericana* cl. S6-7, *P.x euramericana* cv. Robusta), with two different plant densities (38461 plant/ha and 83333 plant/ha) are being tested. Trees were planted using 25cm long hardwood cuttings obtained from the Poplar Research Institute Novi Sad. The cuttings were stored at 4^0 and than soaked in water for 24 hours prior to planting. Cuttings were planted to a depth of 22-23cm. Above ground biomass was harvested at the and of the first growing season. Measurement trees were weighted fresh separately for wood and bark in the field and a random sub sample of trees was taken from each plot to estimate moisture content. Samples were dried to a constant weight at 60^0C and at 105^0C in a forced air drying oven. Biomass production was calculated on an oven dry weight per ha basis.

After natural seasoning of samples for one month at room temperature, wood was ground into wood flour suitable for pellet pressing. Pellets were made in a special device, and pellets weight ranged between 0.35 and 0.64g. The pellets were combusted in the adiabatic calorimetric bomb (DIN 51 708). The changes in calorimetric bomb were measured in three repetitions for each sample. Correction factors for the formation of acids were not included in the gross heat of combustion (higher heating value) calculations.

3. RESULTS AND DISCUSSION

Diameter at breast height and seedling height was measured on the selected samples in field tests. Immediately after felling, the mass of freshly cut trees was measured and the bark was measured after barking in the green state. The specimens were taken for moisture content measurement. After the biomass drying in the laboratory, it was kiln dried and its oven-dry weight was measured (Table 1)

***Table 1**: Average tree parameters and oven dry weights of stem and bark*

Clone	Stem dimensions		Average weight, DM kg		
	Diameter, cm	Height, m	Stem with bark	Bark	Wood
Plant density 38461 trees/ha					
Ostia	2.8	2.95	0.590	0.049	0.541
53/86	1.9	3.30	0.433	0.097	0.336
19/66	2.5	3.30	0.620	0.120	0.500
I-214	1.9	2.60	0.310	0.054	0.256
S6-7	2.5	3.65	0.748	0.129	0.619
Robusta	2.1	3.50	0.625	0.088	0.537
Plant density 83333 trees/ha					
Ostia	1.0	2.40	0.083	0.028	0.055
53/86	1.2	2.90	0.105	0.031	0.074
19/66	1.8	3.27	0.260	0.068	0.192
I-214	1.6	2.70	0.156	0.048	0.108
S6-7	1.6	2.50	0.157	0.043	0.114
Robusta	1.1	2.30	0.113	0.036	0.077

The results in Table 1 show significant differences in tree diameters and heights, depending on planting density. The consequences of denser plantings are significantly lower diameters, especially cl. Ostia (drop for about 64%) and Robusta (for about 48%). Other clones range in the interval between 16% for the cl. I-214 (min) and 37% (cl. 53/86 and S6-7). The changes of seedling height are not so prominent, and the maximal values are attained by cl. S6-7 and Robusta. The changed tree sizes, which are the consequence of significantly greater planting density, result also in a significantly lower biomass yield. Based on the weights of measured plants, biomass ranges up to 85% (cl. Ostia and Robusta), i.e. more than 70% for cl. 53/86 and S6-7. The minimal value (cl. I-214) amounts to only a half of the biomass weight reached in the lower-density plantation.

Biomass yield per unit area depending on the plantation density was calculated based on the weight of test trees and the number of plants. The quantity of bark per hectare of plantation was calculated based on the bark percentage. Due to the fact that this study deals with the biomass of very young trees, practically one-year-old seedlings in which bark percentage is very high, and because of great differences in diameters of the study mean trees, bark weight per unit area is presented separately, disregarding the fact that the bark is not removed from so young plants, i.e. the trees are not barked before chipping. However, as the bark has a relatively high upper calorific value, it is significant to present the percentage of bark in the total energy released by biomass combustion

The study results of biomass yield after the first year show (Fig.1.) that the increase of planting density has not the same effect on all the study clones. Namely, cl. I-214 shows the rise of biomass yield for about 8%, i.e. if only the bark yield is taken into account, it is the increase of more than 90%. Biomass yield of the clone PE 19/66 has a downward tendency for about 9% (higher yield of bark for about 23%). The clones Ostia and Robusta are significantly behind, because their yield is lower for 60%. Maximal values of biomass yield in the plantations with 38,461 plants/ha were attained by the clones S6-7 (28,769 t/ha year) and PE 19/66 (23,846 t/ha year). It should be noted that PE 19/66 had the maximal yield also in a denser plantation (21,667 t/ha year). Clone S6-7, with 13,083 t/ha year, is the second by the yield in a denser plantation, although this is only cca 55% of its yield attained in the thinner plantation.

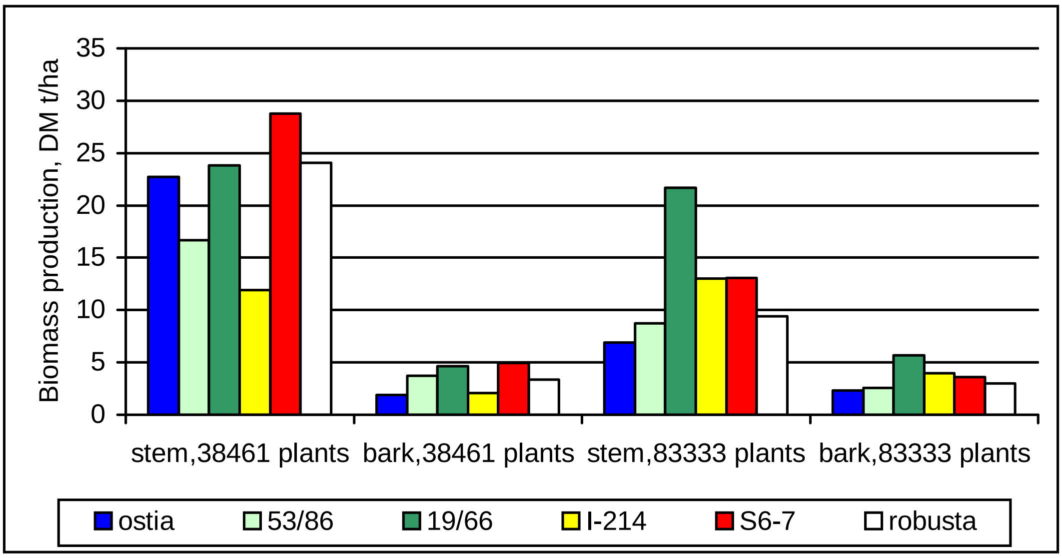

Fig.1. *Biomass production after first growing season*

In spite of the higher plant density the biomass production figure is generally in accordance with other studies, reporting biomass production of 10 to 12t dry wood/ha year [15]; the one-year-old shoots of willow clones (52500 plants/ha) also produced about 12t dry wood/ha [14]. Jiranek and Weger [7] referred that natural clones grow slower than the hybrids, and in good natural conditions annual yield of best poplar clones is expected to be over 15 t/ha of dry biomass. The yield after first year (18000 cutting/ha) ranges from 2.2 to 3.6t DM/ha for poplar clones and 2 to 2.5 t DM for willow clones [8]. After the first of four years rotation cycle in medium density poplar plantations (10000 stems/ha) mean annual increment was 10 to 12 t DM/ha [11]. Riddel-Black et al. [16] reported that yield of six poplar clones (16500 stools/ha) after first growing season was 4.88 to 9.54 t DM/ha. The greatest production of 11.25 t/ha annually can achieved in experimental plantations with one-year rotations in the production process of 9 years with 40000 trees/ha [9], as well as the fact that plantation establishment and tending, felling, manipulation and preparation for combustion is far simpler and economical than biomass resulting from other forms of production.

To be able to assess the amount of energy obtained from the unit area in two study planting densities, by plantation clear cutting after one-year rotation, the calorific values – higher heating values, were determined for wood and bark specimens of the study clones [9,10].

The analysis of the calorific value of the study poplar wood and bark shows that the calorific value ranges within the interval from 15.68 MJ/kg (min) for the clone I-214, to 21.145 MJ/kg (max) for the clone S6-7. The bark calorific values have a narrower range, between 15,539 MJ/kg and 19,808 MJ/kg and they also have both positive and negative deviations from the respective wood calorific values. The values calculated for unbarked wood show that cl. I-214 (15,787 MJ/kg) has the min value and that the max value was recorded for clone S6-7 - 20,505 MJ/kg.

The amount of energy that could be produced by the combustion of wood of the study clones was assessed based on the number of trees per unit area and the mass of mean trees of each individual clone, separately for wood and bark, and for the whole tree (based on bark percentage). It is presented in Table 2.

Table 2: *Calculated amounts of energy per unit area of plantation*

Clone	Energy, GJ/ha		
	Wood	Bark	Stem with bark
Plant density 38461 trees/ha			
Ostia	360.169	37.338	398.993
53/86	242.267	62.520	315.144
19/66	335.004	71.712	407.051
I-214	154.385	33.741	188.728
S6-7	503.420	87.735	589.908
Robusta	406.823	64.599	470.159
Plant density 83333 trees/ha			
Ostia	78.511	46.212	121.622
53/86	115.613	43.283	160.064
19/66	278.703	94.962	396.354
I-214	141.104	64.964	205.215
S6-7	199.820	63.365	268.267
Robusta	126.402	57.233	184.187

The calculated amounts of energy show that there is a similar tendency as in the calculation of biomass yield. Max value is recorded for the clone S6-7 (589,908 GJ/ha) in the plantation with 38,641 trees per hectare. The minimal amount of energy is produced by cl. I-214 (188,728 GJ/ha). Robusta and PE19/66 have the advantage over the other study clones in the plantations with a lower number of trees. It is interesting that the heating value liberated by the combustion of PE19/66 trees is similar also in a denser plantation (396,354 GJ/kg) and that the drop is only 3%, which is minor compared to the drop of almost 70% for Ostia or 61% for Robusta. Clone I-214 showed a slight increase (cca 8%) in the denser planting, which is explained by insignificant changes of biomass yield.

4. CONCLUSIONS

The analysis of results obtained by measuring and computing the yield of biomass (and energy) in two field tests with different planting densities, i.e. in the tests with a great number of plants per unit area, shows that in such studies it is necessary to know the characteristics of individual clones. The reaction of the clones to increased planting density is very different. Evidently, the clones I-214 and PE 19/66 are the least susceptible to higher planting density. Of course, due to its significantly higher basic density, clone PE 19/66 is much more interesting, because its biomass yield is in both cases significantly higher.

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