

Short rotation plantations with high plant density

(Rövid vágásfordulójú, nagy sűrűségű ültetvények)

Dr. Sasa Orlović – Dr. Bojana Klasnja

Institute of Lowland Forestry and Environment,

Antona Čehova 13, Novi Sad,

Serbia and Montenegro

Abstract

*Experimental field plantations were established in experiment estate “Kacka suma”. In the field trial 6 poplar clones (*P.x euramericana* cl. 4, *P.nigra* cl.5, *P deltoides* cl.2, *P.x .euramericana* cl.1, *P.x euramericana* cl. 3, *P.x euramericana* cl.6), with two different plant densities (38461 plant/ha and 83333 plant/ha) are being tested to examine the biomass capacity of these clones.*

Keywords: poplar clones; plantation of heigh density, biomass production

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. 4, *P.nigra* cl.5, *P deltoides* cl.2, *P.x .euramericana* cl.1, *P.x euramericana* cl. 3, *P.x euramericana* cl.6), 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 4⁰ and than soked 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 of the first growing season. Measurement trees were weighted fresh separately for wood and bark in the field and a random subsample of trees was taken from each plot to estimate moisture content. Samples were dried to a constant weight at 60⁰C and at 105⁰C 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 calculations.

The results in Table 1 show significant differences in tree diameters (Dbh) and heights (H), depending on planting density. The consequences of denser plantings are significantly lower diameters, especially cl. 4 (drop for about 64%) and cl.6 (for about 48%). Other clones range in the interval between 16% for the cl. 1 (min) and 37% (cl. 5 and cl.3). The changes of seedling height are not so prominent, and the maximal values are attained by cl. 3 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. 5 and cl.3. The minimal value (cl. 1) amounts to only a half of the biomass weight reached in the lower-density plantation.

Table 1: Average tree parameters and oven dry weights of stem and bark
(Az átlagos fa paraméterek és a törzs, valamint a kéreg tömege abszolút száraz állapotban)

Clone	Stem dimensions		Average weight, DM kg		
	Dbh cm	H m	Stem with bark	Bark	Wood
<i>Plant density 38461 trees/ha</i>					
cl.4	2.8	2.95	0.590	0.049	0.541
cl.5	1.9	3.30	0.433	0.097	0.336
cl.2	2.5	3.30	0.620	0.120	0.500
cl.1	1.9	2.60	0.310	0.054	0.256
cl.3	2.5	3.65	0.748	0.129	0.619
cl.6	2.1	3.50	0.625	0.088	0.537
<i>Plant density 83333 trees/ha</i>					
cl.4	1.0	2.40	0.083	0.028	0.055
cl.5	1.2	2.90	0.105	0.031	0.074
cl.2	1.8	3.27	0.260	0.068	0.192
cl.1	1.6	2.70	0.156	0.048	0.108
cl.3	1.6	2.50	0.157	0.043	0.114
cl.6	1.1	2.30	0.113	0.036	0.077

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 (Table 2) 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 calorific value, it is significant to present the percentage of bark in the total energy released by biomass combustion

**Table 2. Biomass production after first growing season
(A biomassza produkció egy tenyészeti év után)**

Clone	Biomass yield, DM t/ha		
	Wood	Bark	Stem with bark
Plant density 38461 trees/ha			
cl.4	20.807	1.885	22.692
cl.5	12.923	3.731	16.654
cl.2	19.231	4.615	23.846
cl.1	9.846	2.077	11.923
cl.3	23.808	4.961	28.769
cl.6	20.653	3.385	24.038
Plant density 83333 trees/ha			
cl.4	4.583	2.333	6.917
cl.5	6.167	2.583	8.750
cl.2	15.999	5.667	21.667
cl.1	8.999	3.999	12.999
cl.3	9.450	3.583	13.083
cl.6	6.417	2.999	9.417

The study results of biomass yield after the first year show (Table 2) that the increase of planting density has not the same effect on all the study clones. Namely, cl. 1 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 2 has a downward tendency for about 9% (higher yield of bark for about 23%). The clones 4 and cl.6 are significantly behind, because their yield is lower for 60%. Maximal values of biomass yield in the plantations with 38461 plants/ha were attained by the clones 3 (28.769 t/ha year) and 2 (23.846 t/ha year). It should be noted that cl.2 had the maximal yield also in a denser plantation (21.667 t/ha year). Clone 3, 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.

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 [13]; the one-year-old shoots of willow clones (52500 plants/ha) also produced about 12t dry wood/ha [14]. Jiranek and Weger [15] 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 [16]. 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 [17]. Riddel-Black et al. [18] 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 be achieved in experimental plantations with one-year rotations in the production process of 9 years with 40000 trees/ha [19], 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, clones 1 and 2 [9, 20] were used. The study values are presented in Table 3.

**Table 3: Average calorific values of wood and bark
(A fa és a kéreg átlagos hőértéke)**

Higher heating value, MJ/kg			
Clone	Wood	Bark	Stem with bark
cl.4	17.131	19.808	17.583
cl.5	18.747	16.757	18.293
cl.2	17.420	15.539	17.070
cl.1	15.680	16.245	15.787
cl.3	21.145	17.685	20.505
cl.6	19.698	19.084	19.559

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 1, to 21.145 MJ/kg (max) for the clone 3. 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. 1 (15.787 MJ/kg) has the min value and that the max value was recorded for clone 3 – 20.505 MJ/kg. These values are somewhat lower than the values of mean gross calorific value 20.293 MJ/kg [21] reported for adult trees. Also, Ciria et al., [22] reported that heating values of 3-5 years old SRIC poplar wood (stem and branches) 18.1 – 18.3 MJ/kg. Calorific value of bark of clone 1 (16.245 MJ/kg) is somewhat higher when compared with value referred by Danon, 16.065 MJ/kg for the same clone, 15 year old [23] and lower with value of black poplar bark (*P. nigra*) which is 17.260 MJ/kg [24].

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 4.

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 3 (589,908 GJ/ha) in the plantation with 38,641 trees per hectare.

The minimal amount of energy is produced by cl. 1 (188.728 GJ/ha). Clone 2 19/66 has the advantage over the other study clones in the plantations with a lower number of trees. It is interesting that the thermal energy obtained by the combustion of cl.2 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 cl.4 or 61% for cl.6. Clone 1 showed a slight increase (cca 8%) in the denser planting, which is explained by insignificant changes of biomass yield.

**Table 4: Estimated energy production
(Becsült energia termelés)**

Clone	Energy, GJ/ha		
	Wood	Bark	Stem with bark
<i>Plant density 38461 trees/ha</i>			
cl.4	360.169	37.338	398.993
cl.5	242.267	62.520	315.144
cl.2	335.004	71.712	407.051
cl.1	154.385	33.741	188.728
cl.3	503.420	87.735	589.908
cl.6	406.823	64.599	470.159
<i>Plant density 83333 trees/ha</i>			
cl.4	78.511	46.212	121.622
cl.5	115.613	43.283	160.064
cl.2	278.703	94.962	396.354
cl.1	141.104	64.964	205.215
cl.3	199.820	63.365	268.267
cl.6	126.402	57.233	184.187

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. As it can be seen in the Tables, the reaction of the clones to increased planting density is very different. Evidently, the clones 1 and 2 are the least susceptible to higher planting density. Of course, due to its significantly higher basic density, clone 2 is much more interesting, because its biomass yield is in both cases significantly higher: two times higher in the thinner plantation (23.846 t/ha compared to 11.923 t/ha).