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PRODUCTION AND ECONOMIC PARAMETERS OF A POPLAR (J 105) COPPICE PLANTATION WITH DIFFERENT LENGTH OF THE FIRST ROTATION IN THE CONDITIONS OF THE BOHEMIAN-MORAVIAN HIGHLANDS

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Abstract

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The paper analysed production and economic effectiveness of a short-rotation coppice plantation, namely J 105, after the first rotation period of 7 and 8 years respectively. The plantation is located in the region of the Bohemian-Moravian Highlands with an annual precipitation of 497 mm and mean air temperature of 8.6 °C. To assess the productivity, the trees were selected according to stem diameter at a height of 10 cm above the ground level and classified into three categories: I) 0–3.0 cm; II) 3.1–7.0 cm and III) > 7.0 cm. Sample trees were selected in each year. The economic effectiveness of the plantation was assessed as the difference between profits and costs for both rotation cycles. The mean annual above-ground biomass production for the 7-year rotation (2012) was 3.15 t/ha and 3.30 t/ha for the 8-year rotation (2013). The low productivity of poplar was due to slow growth (approx. 0.5 m in height) and drought in the first year after the plantation was established. The economic effectiveness for the 7-year rotation was CZK –5,300/ha and CZK +17,500/ha for the 8-year rotation. It was due to current total aboveground dry mass increment in the 8th year of rotation.

Keywords: short rotation coppice, poplar, J 105, productivity, biomass, economy

INTRODUCTION

Worldwide, the role of plantations of fast-growing trees are discussed mainly in connection with global deforestation (Sands, 2005). In the European and Czech context, the goal of fast-growing tree plantations is increasing the share of renewable energy sources (Lewandowski *et al.*, 2006; Roedl, 2010).

To the current share of renewables in the Czech Republic (8.2%), biomass contributes 3%, which is 1.9 million tons of dry mass per year (Weger and Jiránek, 2003). According to the National Action Plan, by 2030, the share of biomass in total energy balance should be 13.5%. In addition to the residual biomass, such as from forests, its planned cultivation on agricultural and other lands has a significant potential. The Czech Republic is among the countries with a high ratio of arable land as a share of total agricultural land (73.8%). Converting part of that land for biomass cultivation could mean the solution of the poor competitiveness of agricultural activity, as well as the overall improvement of environmental conditions of the landscape (Weger and Jiránek, 2003; Kravka *et al.*, 2012).

The main planned biomass cultivation types are coppice plantations of fast growing trees (SRC – Short Rotation Coppice). In the Czech Republic, the area of these plantations is currently 1,500 ha. Their annual production is up to 15 t of dry mass per 1 ha, with a rotation period from 3 to 6 years, while the life of plantations ranges from 20 to 35 years (Havlíčková *et al*., 2006; Weger, 2014). Researchers estimate the total production potential of fast growing tree plantations in the Czech Republic for the years 2015 to 2020 to range from 4 to 6 million tons of dry mass per year (Weger and Jiránek, 2003).

Among the most common and promising tree species in coppice plantations in the Czech Republic are willow clones and poplar hybrids, especially *P. nigra* × *P. maximowiczii* J 105 or Max 4, or J 104, Max 5 (Trnka *et al*., 2008; Weger, 2014). Existing results show that the production of these clones in the Czech Republic may be as high as 13.9 t/ha/year and 14.6 t/ha/year, respectively (Trnka *et al*., 2008; Weger, 2008).

In addition to the tree species and clone, the stand and proper management also affect the production of the plantation (Trnka *et al*., 2008). Lewandowski *et al*. (2006) and Havlíčková *et al*. (2006) have noted the details of the stand suitability for the establishment of plantations. The limiting factors in the first years after the establishment of plantations include weed competition and weather (e.g. Trnka *et al*., 2008). Stand conditions along with the price of wood chips are also the basic of economic efficiency of plantations (Havlíčková *et al*., 2006).

The aim of this paper is a production and economic analysis of a coppice plantation in the Bohemian-Moravian Highlands during the first rotation period at the age of 7 and 8 years respectively. Mortality, growth, and production of Japanese poplar J 105, as well as the total cost and profitability of the plantation were evaluated.

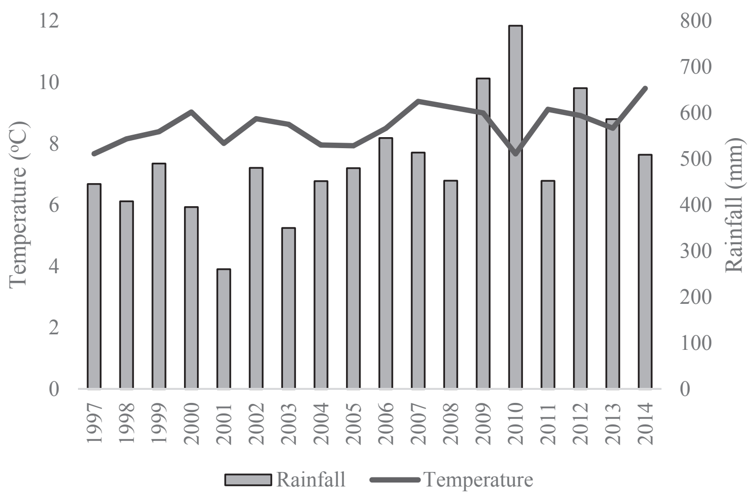
MATERIALS AND METHODS

The studied plantation is located in the foothills of the Bohemian-Moravian Highlands near the village of Deblín at an altitude of 500 meters above sea level (GPS 49.3130022N, 16.3291850E). The plantation owner is the Forests of the City of Brno, a. s. According to the bonit land ecological unit the plantation site is classified as belonging to a moderately warm, humid climatic region. Its soils are moderately heavy to heavy, non-skeletal, and deep. The mean annual temperature is 8.6 °C, while annual rainfall reaches 497 mm (Fig. 1). The estimated production of fast growing tree species here should reach 3.60 to 4.35 tons dry mass/ha/year (Geoportal MŽP, 2013).

The plantation was established by planting of cuttings in March 2006 following an area-wide ploughing of former farmland. The planting used the following clones of poplar – J 105 (*P. nigra* L. × *P. maximowiczii* Henry "Maxvier"); J 104 (*P. nigra* L. × *P. maximowiczii* Henry "Maxfunf") and willow S 195 (*S. x rubens* Schr.). Tree spacing was 2.5×0.3 m at a density of 12,100 pieces/ha in rows oriented SSW – NNE. The production area of the plantation is 1.790 ha. Willow S 195 was used as a buffer, while poplar J 104 was planted only at east edge of the J 105 area. The survey area covers most of the 1.115 ha plot on which poplar J 105 was planted.

Production Survey

The production parameters of the plantation were determined using inventory survey and destructive analysis of sample trees. The survey took place on all plantation at the end of the growing season in 2012, i.e. 7 years after planting. Immediately after the survey completion, half of the plantation was harvested. On the remaining part of the plantation, the same survey was repeated one year later. Here



1: *Dynamics of annual temperatures (°C) and annual rainfall (mm) during the period 1997–2014 from the meteorological station Sedlec (Náměšť nad Oslavou, Czech Republic, 49°10'15.0"N 16°07'14.0"E, altitude 474 m a.s.l.)*

harvesting of the rest of plantation took place after the survey as well.

In small plots, respectively in parts of the tree rows 2.5 m long, spaced 25 m apart, all poplars were registered and their diameter at 0.1 meters above the ground was detected. The trees were classified into the following diameter classes: I) 0–3.0 cm, II) from 3.1 to 7.0 cm, III) > 7.0 cm. In the inventory of 2012, the sampling intensity was 9.60%, while in 2013, it was 10.08%.

Sample trees were taken to determine the volume of poplars. Their stem volume in sections representing each year was determined according to the height increment. Number of sample trees for individual years and diameter classes were as follows: 2012 (total of 49): I – 10, II – 32, III – 7; 2013 (total of 90) I – 13, II – 56, III – 21.

To detect the dry weight of dendromass, each year 12 sample trees in the following diameter classes: I – 3, II – 6, and III – 3 (total of 24 sample trees) were collected. For each sample tree, The weight of the stem and branches in the fresh state and after drying to constant weight at 80 °C were determined.

Data Analysis

We have applied the Chapman-Richards growth function (Zeide, 1993) to the data of total height of a tree (*TH*) for each diameter class:

$$TH = a(1 - e^{-bt})^c, \quad (1)$$

where *a*, *b*, and *c* are the coefficients of the function and *t* is age of a tree.

Curves of current height annual increment (CAI_h) for the same data was constructed by function:

$$CAI_h = abce^{-bt}(1 - e^{-bt})^{c-1}, \quad (2)$$

where the meaning of symbols is the same as in equation 2.

The total volume production of stems on the plantation was calculated by multiplying the weighted average volume of one stem on the plantation and the total number of trees obtained from the inventory. Furthermore, the weighted volume variance of one poplar and confidence interval, in which the average volume of one poplar lies were calculated. The confidence interval for the total volume of stems on the plantation was calculated too. The results were determined for 95% confidence level. Furthermore, the needed number of samples to achieve the result desired with 95% confidence (probability of correct result) and the required accuracy of 10% was counted.

The weight of total dry dendromass per ha was determined by calculating the average dry weight of sample trees in individual diameter classes and multiplied it by the number of individuals per ha in a given diameter class. The average values of the dry mass weight of the sample trees were compared each other using the Kruskal-Wallis ANOVA, separately for 2012 and for 2013.

The dry weight of the stems and branches were calculated as the average proportion of dry weight of stems and branches of total dendromass multiplied total dry weight of dendromass by these proportions. Kruskal-Wallis ANOVA for comparison of the average proportion of the dry weight in branches and stems among the thickness classes was carried out separately for the years 2012 (7-year rotation) and 2013 (8-year rotation).

Economic Appraisal

The aim of the economic appraisal was to determine the difference between cost and revenue. The interest rate and eventual subsidies were disregarded. The difference between revenue and cost was determined for 2012 (7-year rotation) as well as for 2013 (8-year rotation).

The expense items were the same for both years and included project development and pre-planting ground preparation, planting material (cuttings), planting, plantation maintenance, and harvesting.

The plantation revenues from cubic meters of wood chips obtained after the harvests in 2012 and 2013 were determined. The amount of chips found in individual years was recalculated to a value representing 1 ha of plantation and multiplied it by the price of one cubic meter of wood chips, which were sold for CZK 644.

RESULTS AND DISCUSSION

The number of individual planted trees decreased from 12,100 pieces/ha to 7,380 after 7 years and to 6,940 pieces/ha after 8 years since the founding of the plantation (Tab. I). Mortality of the analysed clone J 105 thus ranged between 39% and 43%. The most critical period for the survival of poplar cuttings is considered the first few years after planting (Trnka *et al.*, 2008; Weger, 2008). Although the cutting mortality in different years was not

I: *Basic parameters of poplars (J 105) 7 and 8 years after plantation establishment*

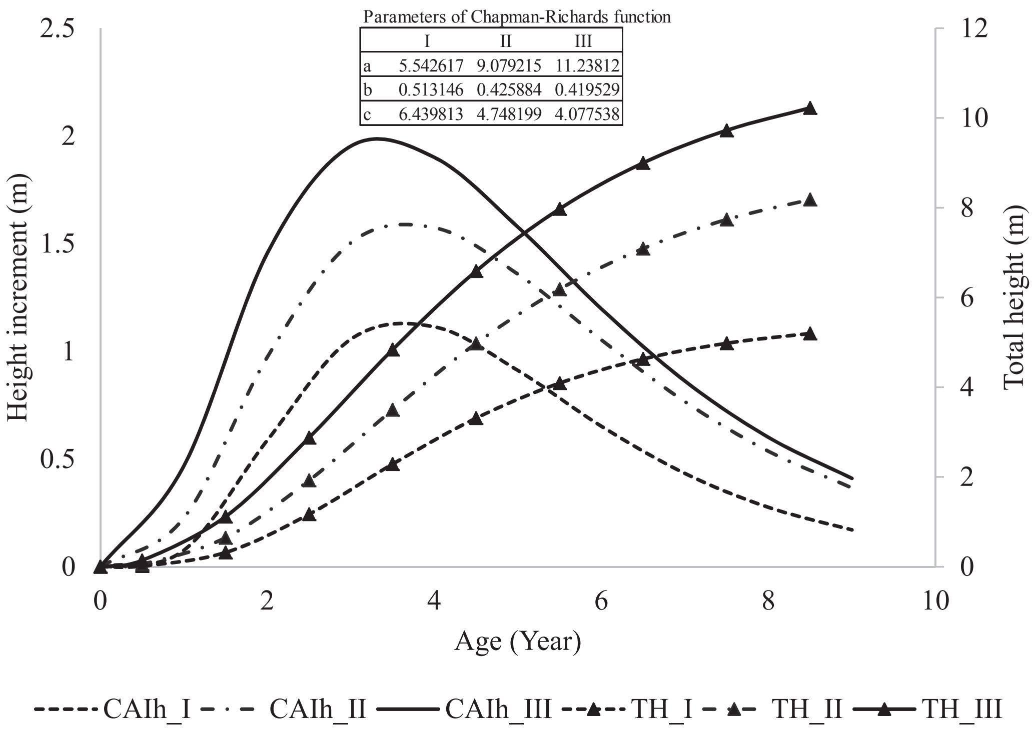
Diameter class		Number of trees per ha (pcs)		Number of trees per ha (%)		Mean tree volume (dm^3)	
		Rotation period		Rotation period		Rotation period	
Class	Interval (cm)	7 years	8 years	7 years	8 years	7 years	8 year
I	0–3.0	1,515	914	20.53	13.16	0.91 ± 0.39	0.90 ± 0.37
II	3.1–7.0	5,323	4,586	72.13	66.05	5.00 ± 2.54	5.43 ± 2.84
III	> 7.0	542	1,444	7.34	20.79	14.38 ± 3.69	18.84 ± 5.32
Total		7,380	6,944	100	100	5.51 ± 4.68	7.91 ± 7.10

under investigation, we can expect that the highest value was achieved the first year after planting. Due to the persistent drought in the spring of 2006, repeated watering was carried out after planting (Ing. J. Neshyba – personal communication). Despite the decrease of poplar density, it would not be considered the specified mortality rate of around 40% as unusual. For instance Trnka *et al.* (2008) reported the same clone mortality from nearby Domanínek plantation in the period from 2001 to 2006 at 36%.

Unfavourable conditions for growth in the first year after planting are evident from the sequence of height increments, which reached a maximum of 0.5 m (Fig. 2). In optimal conditions, we can expect growth increase in the first year at around 1.5 to 2 m (Weger, 2003; Weger, 2014). Maximum values of annual height increment around 2 m were achieved on the plantation only during its peak between the 3rd and 4th year. Low growth potential of poplar in the first rotation at a specific location is also shown by the total maximum height attained, which for eight years has reached less than 11 meters (Fig. 2). Trnka *et al.* (2008) indicate the maximum height of the same clone at the rotation period of six years at Domanínek plantation some 25 kilometres away up to 14 m. In contrast, Fajtman *et al.* (2009) report after the 7-year rotation period, also at Domanínek plantation, maximum height of the 105 J clone only around 8.5 meters.

Results of the production survey have shown considerable variability in growth, but also in production among individual trees. The largest share of volume production belongs to individuals with a diameter between 3 and 7 cm (72% in 2012 and 66% in 2013). The volume of sample tree wood in 2012 (7-year rotation) ranged from 0.9 dm^3 to 14.4 dm^3. In 2013 (8-year rotation) minimal volume was similar, while maximal volume amounted up to 18.8 dm^3 (Tab. II).

In terms of the dry weight of total dendromass of individuals, a detectable difference between the average values in the individual diameter classes in both years was found (2012: p-value = 0.0093; 2013: p-value = 0.0089). Conversely, the percentage of dry weight of stems did not differ significantly among the different diameter classes in both years (p-value > 0.05). The resulting dry mass content of



2: *Height growth dynamics of poplar (J 105) in diameter classes (CAI_h – current annual increment, TH – total height, diameter classes: I) 0–3.0 cm, II) 3.1–7.0 cm, III) > 7.0 cm)*

II: *Production parameters of poplar (J 105) during the seven-year and eight-year rotation*

Rotation period	Stem volume (m^3/ha)	Mean annual volume increment (m^3/ha)	Stem dry mass (t/ha)	Branches dry mass (t/ha)	Total aboveground dry mass total (t/ha)	Mean annual increment (t/ha/year)
7 years	40.65	5.81	17.69	4.33	22.02	3.15
8 years	54.90	6.86	21.16	5.24	26.40	3.30

III: *Cost structure (CZK/ha) of poplar (J 105) plantation Deblín*

Cost	Project and soil preparation	Planting material and regeneration	Weed control, watering	Harvesting costs	Total
CZK	8,399	43,042	20,096	7,485	79,022
%	10.6	54.5	25.4	9.5	100

IV: *Economic effectivity of poplar (J 105) plantation Deblín within 7 and 8 year rotation*

Rotation period	Total cost (CZK /plantation)	Total cost (CZK/ha)	Total income (CZK/ha)	Income – cost (CZK/ha)
7 years	79,022	68,417	63,122	–5,295
8 years	79,022	68,417	85,930	17,513

stems was 80.32% in 2012 and 80.14% in 2013. For the percentage share of branches, no significant differences were demonstrated (p-value > 0.05) between diameter classes. The share of dry mass of branches in 2012 amounted to 19.68% and 19.86% in 2013.

The total amount of dry mass on the plantation for the 7-year rotation period (harvest in 2012) reached 22.0 t/ha, and for the 8-year rotation 26.4 t/ha (Tab. II). The mean annual above-ground dendromass production for 7-year rotation was 3.15 t/ha/year and for the 8-year rotation 3.30 t/ha/year (Tab. II).

The achieved annual of dry mass increment values are indeed on the anticipated level of yield (Yield Maps), however with the assumption of prolonged rotation period (8 years). The reason for low production during the first rotation period is probably low growth in the first year after establishment of the plantation (Fig. 2). Overall, the production of the J 105 clone on the plantation is at the lower level of yield for the Czech Republic (Weger, 2014). For subsequent rotation, we can still expect an increase (Weger, 2003). This is indicated by the height of coppice in the years 2013 and 2014, after one and two years, respectively, from the first harvest, as the two-year sprouts reached more than three meters in height.

The total cost of the plantation establishment, i.e. nearly CZK 80,000/ha, ranged about CZK 20,000 to CZK 40,000 over the commonly cited limit for the Czech Republic (Weger, 2014). This was mainly due to the high cost of plantation maintenance (Tab. III). The planting material and planting cost were also abnormally high.

Despite such high cost, there was still a positive economic result for the 8-year rotation period (harvest in 2013). The revenue for the 8-year rotation exceeded the cost by CZK 17,500/ha. It was due to current total aboveground dry mass increment in the 8th year of rotation. After the 7-year rotation, the difference between revenue and cost was negative due to high cost and slow grow in the early stadium of plantation (CZK –5,300/ha, Tab. IV).

CONCLUSION

For the 7-year and 8-year rotation in the first harvest cycle, the total production of the 105 J poplar plantation at Deblín amounted to 3.15 tons and 3.30 tons of dry mass per year/ha, respectively. The cause of low yields was the weak growth of poplar in the first year after planting due to drought. The upper height of poplar after eight years only slightly exceeded 10 m.

The highest cost items of the plantation were planting and the purchase of planting stock (CZK 43,000/ha). Also maintenance such as protection against weeds and watering in the first year after the founding (CZK 20,000/ha) was significant. The difference between revenue and cost for the 7-year production cycle reached negative CZK 5,300/ha. For the 8-year cycle, the economic outcome amounted to positive CZK 17,500/ha.

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