ESTIMATION OF ABOVE GROUND WOODY BIOMASS OF SRC HYBRID POPLAR CLONE J-105 IN DIFFERENT FERTILIZER TREATMENTS IN CZECH-MORAVIAN HIGHLAND

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ABSTRACT

Short rotation coppice poplar hybrid clone J-105 *(Populus nigra* x *P. maximowiczii)* is studied as an alternative source of bio-energy in the region of Czech-Moravian Highland. The plantation was established in 2001 at the locality Domanínek in the vicinity of Bystřice nad Pernštejnem (Czech Republic, 49°32'N, 16°15'E and altitude 530 m a. s. l.) where mean annual rainfall of 609 mm and mean annual temperature of 7.2°C was recorded between 1981 and 2010. The total area planted with the clone was close to 1.5 ha with total plantation area being close to 3.5 ha. The plantation with planned density of 9,216 trees ha^{-1} was established on the former agricultural land and the length of the rotation cycle was set to 6-8 years. At the beginning of the second rotation period i.e. in spring 2009 (following winter harvest), the plantation was divided into four randomized blocks with different nutrient treatments and three replicates (4×3). These treatments comprised of application of mineral NPK fertilizer (nitrogen 305 kg ha^{-1}, phosphorous 154 kg ha^{-1} and potassium 291 kg ha^{-1}), sewage sludge (4200 kg/ha^{-1}) and ash (1000kg ha^{-1}) and lime (5 ton ha^{-1}), while control was with natural nutrients content only (deposition and leaves mineralization). The objectives of the study were to estimate the above ground annual yields (based on allometry and stem inventory), the mortality and the shoot to stump ratio as the main productivity characteristics.

Key words: short rotation coppice, bio-energy, poplar, allometry, biomass dry matter content (dmc), shoot ratio

INTRODUCTION

Short-rotation coppice of fast growing woody biomass production represents the good source of alternative energy. This production is suitable where food production is low and also profitable due to soil and/or climate conditions. Short rotation forestry was introduced since 1960’s with research focused on growing willows in Sweden (Siren et al. 1987). Fast growing broadleaved trees such as poplar and willow, switched to producing woody biomass for energy after the 1970’s oil crisis. Coppice of the short rotation forestry refers to the tree cuttings at the base of trunk and mimics natural disturbance process for instance fire and resulting in the re-growth of new shoots from roots and or stump (Blake 1983). Coppicing could increase the final biomass production and is an alternative for replantation (Sennerby-Forsse et al. 1992). With respect to water use, biomass productivity of short rotation coppice (*Populus nigra* × *P. maximowiczzii*) is more efficient than the most of the broadleaved species. However annual rainfall more than 450-500 mm is needed to ensure their profitable yields in the conditions of Czech Moravian highlands (Fischer et al. 2011). Apart from the water availability, the soil fertility constitutes one of the most preconditions for successful growing. Fertilization is typically one of the least expensive treatments for increasing yields. The establishment of new plantation can be improved by fertilizing at the time of planting to increase the fast growth rates, allowing the trees to overtop competing vegetation and form established stands earlier, ultimately reducing the time period between planting and harvest (Miller, 1981). Fertilization in fast growing hybrid poplar (*Populus sp*.) is more effective (Van den Driessche, 1999). The effects of the fertilizers in the second and third growing seasons of the poplar sp. is relatively small and negative effects of nitrogen fertilization on growth of some poplar such as clones 33 and 794 (DesRochers et al. 2006). In short rotation forestry (SRF) system fertility manage by the nutrient cycle in temperate region or under natural forest conditions, the nutrients leached from soils are usually almost negligible (Heilman et al 1998). In agricultural soils, enriched source of main nutrients (N, P, K and Ca) is maintained by the frequent use of mineral and organic fertilization. (Schwabisch 1994). In case of leaf growth, there is a requirement of such huge amount of nutrients but in some cases of poplar clones, mineral fertilizers can restricts the growth of stems (Van den Driessche 2007.). In case of some clonal experiments, comparison clones such as J-105, J-104 and P-473, highest survival rate was observed in J-105 of Czech Moravian Highlands (Trnka et al. 2008). Coppice cultures are specified by a high shoot density and high stool density and studies of mortality is dependent on intraspecific competition in crowded populations and shoots size and mortality was studied (Laureyens et al. 2005).

Aim of the presented paper is to estimate the biomass (dmc) standing stock annual yields (based on allometry and stem inventory), mortality and the shoot to stump ratio as the main productivity characteristics.

MATERIAL AND METHODS

Site description and management regimes

The plantation was established in April 2001 with planned high density 9,216 trees ha^{-1} on arable land and the length of the rotation cycle was set to 6-8 years for verification of performance of selected poplar hybrid clone J-105 (*Populus nigra* × *P. maximowiczii*). The total area is close to 1.5 ha with total plantation area being close to 3.5 ha. The site is located in Domanínek near Bystřice nad Pernštejnem (Czech Republic, 49^{o}32’N, 16^{o}15’E and altitude 530 m a.s.l.) where mean annual rainfall of 609 mm and mean annual temperature of 7.2^{o}C was recorded between 1981 and 2010. The area is wet and generally cold temperature climate typical for this part of Middle Europe with mingling continental and maritime influences. The site is suitable for the short rotation forestry based on *Populus sp*. and their clones according to Havlickova et al. (2006) as the area belongs to the climatic region (no. 7). Weather parameters were obtained from meteorological station Bystrice nad Pernstejnem (Czech Republic). At the beginning of the second rotation period in spring 2009 (following winter harvest), the plantation was divided into four randomized blocks with different nutrient treatments and three replicates (4×3). These treatments comprised of the application of mineral NPK fertilizer (nitrogen 305 kg ha^{-1}, phosphorous 154 kg ha^{-1} and potassium 291 kg ha^{-1}); the sewage sludge (21,000 kg ha^{-1} of raw sludge containing 4200 kg. ha^{-1} of dry matter) and ash (1000 kg ha^{-1}); and the lime (5 ton ha^{-1}); while control was with natural nutrients content only (deposition and leaves mineralization). The mineral fertilizers used were urea (N 46%), amofos (P 52%) and potassium salt (K 58%). Lime as a source of Ca and Mg was used to improve the soil acidity (pH).

Tab. 1: Climatic and soil conditions on selected research site

Climatic characteristics

Parameter	Units	Jan-Dec	Apr-Sep	Jun-Aug	Dec-Feb
Mean air temperature (1961-1990)	°C	6.6	12.8	15.5	-2.7
Mean air temperature (2002-2010)	°C	7.6	14.2	16.9	-2.3
Mean precipitation sum (1961-1990)	Mm	580.6	359.6	208.3	113

Soil characteristics

Component	Units	Depth (cm)			
		0-24	24-66	66-94	94-130+
Silt	wt %	50	46.1	38.7	19.6
Clay	wt %	15.8	26.3	18.6	13.3
Bulk density	g/cm3	1.55	1.64	1.59	1.64
Organic matter	wt %	2.65	0.28	0.14	0.14
Total nitrogen	wt %	0.16	<0.05	<0.05	<0.05
pH (KCl)		5.9	5.4	4	3.4
Available P	mg/kg	148	1.3	0.9	24
Available K	mg/kg	151	91	62	76
Available Mg	mg/kg	143	230	278	291
Available Ca	mg/kg	1230	1353	748	652

Statistical analysis

An analysis of variance (ANOVA) was used to test the significance of differences in stool mortality, shoot to stump ratio and above ground woody biomass (dmc) standing stock between fertilizers in different years. The analysis was performed with the statistical package STATISTICA 9 (StatSoft, Inc., USA).

RESULTS AND DISCUSSION

Mortality

Stool mortality rate naturally increased with the increase in the year but in some treatments, it stayed constant like e.g. in lime treatment. In case of control, the mortality was the lowest but the difference being non-significant. Interestingly, in some rare cases (e.g. in control) the mortality can be lower in the following year because of some shoots regeneration after years. However, its impact on the overall mortality was of minor interest. After the second year of the second rotation period, the average mortality of stools was recorded to be 17.86% in case of mineral, 22.62% in case of sewage sludge and ash, 5.35% in case of lime and 15.48% in case of control and third years it is varied as 20.83% in mineral, 22.62% in sewage sludge and ash, 5.36% in lime and 12.20% in the control (Table 2). In 3rd years coppicing stool mortality increased but ANOVA results had no significant difference [$p>0.05$ (Fig. A & D)].

Shoot to stump ratio

Aafter coppicing, many shoots sprouted from the stumps. After the 2nd and the 3rd year an average of 4 or 5 five shoots emerged from the stumps. The fertilizers mineral and the sewage sludge and ash had an average of 4 shoots per stump. The fertilizers lime and the control had an average of 5 shoots per stump. All fertilizers treated and non-treated shoots to stump mean and standard deviation ratio according to year (Table 2). After ANOVA results, it was observed that all fertilized and non-fertilized shoot to stumps ratio had no significance differences [$p>0.05$ (Fig B & E)].

Biomass

We estimated the above ground woody biomass (dmc) standing stock in *Populus* hybrid clone J-105. We used the allometry power function equation (unpublished data) for the different fertilizer treatments including control. After the coppicing in 2nd year, an average biomass (dmc) production 16.67 ton ha^{-1} was observed in mineral treatment, 15.12 ton ha^{-1} sewage sludge and ash, 15.34 ton ha^{-1} lime and 15 ton ha^{-1} in control and after 3rd years, it was increased by almost two times in among all fertilizer and non-fertilizer treatments. The *Populus* hybrid clone J-105 mean and standard deviation of 2nd and 3rd year biomass production is shown (Table 2). The ANOVA results showed no significant difference ($p>0.05$). The figure 1(C & F) shows biomass (dmc) production standing stock in fertilizer and non-fertilizer treatments, after the 2nd year (2010) and the 3rd year (2011). We also estimated the annual above ground woody biomass (dmc) increment in standing stock from 2nd to 3rd year. An average biomass (dmc) increment is 13.62 ton ha^{-1} in mineral, 13.82 ton ha^{-1} in sewage sludge and ash, 9.16 ton ha^{-1} in lime and 14.49 ton ha^{-1} in control. Annual mean and standard deviation of biomass increment among fertilized and non-fertilized (Table 3) and ANOVA results showed no significant differences ($p>0.005$) figure 1 (G).

Tab. 2: Average mortality of stool in percentage, number of shoots per stump and above ground of woody biomass (dmc) standing stock ton per ha-1 in different fertilizer treatments, the mineral (NPK), the sewage sludge and ash, the lime and the control (non-fertilized) after the first coppicing 2nd (2010) and 3rd (2011) year, respectively.

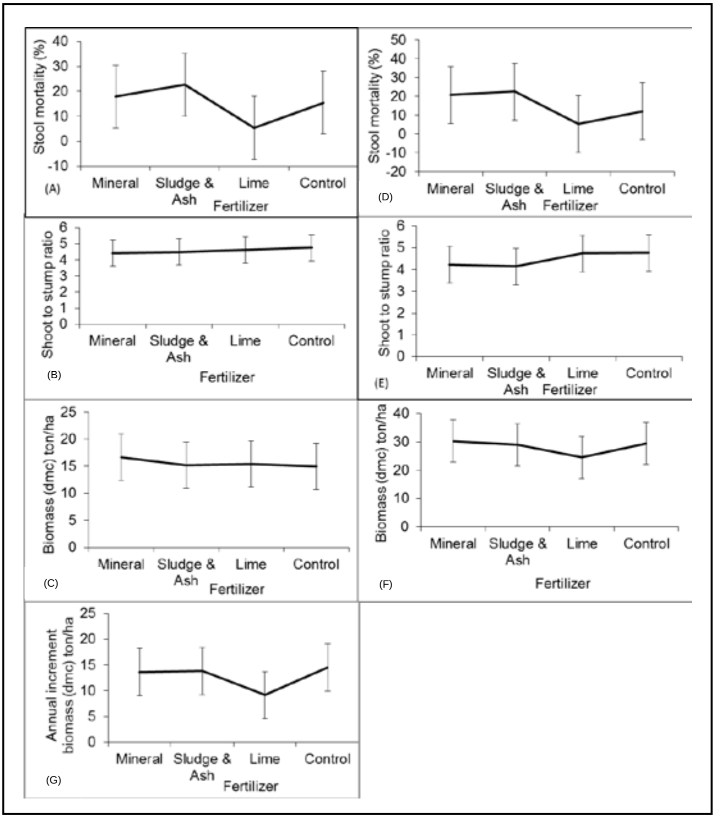
Year	Fertilizer	Traits		
2010		Stool mortality (%)	Shoot to stump ratio	Biomass production (dmc) t/h
		Mean±SD	Mean±SD	Mean±SD
	Mineral	17.86±14.29	4±1	16.67±4.35
	Sewage sludge and Ash	22.62±9.83	4±0	15.12±3.23
	Lime	5.36±4.72	5±0	15.34±3.11
	Control	15.48±5.74	5±1	15.00±1.42
2011	Mineral	20.83±17.89	4±1	30.29±6.68
	Sewage sludge and Ash	22.62±8.44	4±0	28.94±4.13
	Lime	5.36±7.78	5±0	24.50±7.56
	Control	12.20±8.10	5±1	29.49±2.57

Tab. 3: Average annual above ground woody biomass (dmc) standing stock increment after the first coppice rotation from 2010 (2nd) to 2011 (3rd) year ton ha-1 in different fertilizer treatments.

Fertilizer	Annual biomass (dmc) increment ton ha^{-1} (mean±sd)
Mineral	13.62±2.36
Sewage sludge and Ash	13.82±2.07
Lime	9.16±5.96
Control	14.49±1.28

Fig. 1: A & D shows shoot mortality (%), B & E shoot to stump ratio, C & F biomass (dmc) ton/ha in 2010 and 2011 individually and G annual biomass increment. Vertical error bars denote confidence interval of 0.95.

2010 2011



CONCLUSION

The study focused on the effect of the fertilisation during the second rotation at 11-year old experimental poplar coppice culture plantation. We estimated biomass (dmc) production of *Populus* hybrid clone J-105 using power allometry equation and inventory. This was used to estimate the biomass production of standing stock for hybrid clone J-105 in different fertilizer treatments and control (non-fertilized). The *Populus* hybrid clone J-105 of shoots per stump, mortality of stools as well as the production of biomass showed no significant difference across all treatments, thus, showing no benefit of fertilisation three years in the second rotation.

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