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PRODUCTION AND ENERGY POTENTIAL OF DIFFERENT HYBRIDS OF POPLAR IN THE SOIL AND CLIMATIC CONDITIONS OF SOUTHWESTERN SLOVAKIA

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ABSTRACT

The paper presents the results of research on production and energy potential of Italian hybrids of poplar (*Populus* spp.) in soil and climatic conditions of south-western Slovakia. The research was carried out on four three-year old Italian hybrids (Monviso, AF-2, Pegaso and Sirio) with two methods of planting and spacing of 2 or 1x0.75 m. The research site is lowland and belongs to the warm and very dry climate region. The soil is moderate (loam), fluvisol with average pH 7.26 and humus content 1.8 %. The evaluation of the production parameters resulted in the following findings: The percentage of rooted cuttings was relatively low, especially in the second planting method. Planted cuttings produced 1.0 to 1.63 shoots in the first growing period. There was no statistically significant impact of the planting method and individual hybrids on the number of shoots. At the beginning of the second growing period (after cutback), some of the individuals, depending on the planting method and hybrids produced up to 12 shoots. Poplars (similarly to willows) showed a gradual dieback (mortality) of shoots. Two years after the cutback (in the third growing period) the number of living shoots on individuals decreased to 2.6 to 4.6. Mortality of the shoots in different hybrids ranged from 48 to 72 %. In the third year, there was

1.3 to 1.7 fold increase in the length of the shoots compared to the average length of shoots in the first year. The diameter of the shoots showed 1.4 to 1.7 fold increase compared to the first year. The highest yield of dry biomass in the third growing period was achieved by clone Monviso, the lowest by Pegaso. The values of the chemical and energy indicators in individual hybrids are not significantly different. From occurring diseases, particularly rust (*Melampsora larici-populina*) negatively affected photosynthetic potential of the studied poplar hybrids.

KEYWORDS: Soil and climatic conditions, poplar, fast-growing tree species, production and energy indicators.

INTRODUCTION

Fast growing energy plants and trees such as poplar are characterized by short-term growth and weight gain significantly exceeding the average growth of other plants during the growing period (Koloničný 2005, Jandačka et al. 2007). Short rotation coppice energy plants have also high efficiency of solar radiation utilization (Hauptvogl et al. 2011). Methods of intensive poplar cultivation in Slovakia are described in Kohán et al. (1981), Kohán (1998, 2001 and 2002), Vojtuš (1978), Varga (1990), Cifra (1971). Well known works in the Czech Republic are Čížek et al. (1992) and Hejmanowski (1975). Cultivation technologies of Italian poplar hybrids have been very precisely developed in Italy, where is a long-term tradition of growing poplars that reach several fold biomass production compared to other tree species. Currently, the majority of the wood biomass used for energy purposes in Slovakia comes from forests (wood processing residues), municipal wood waste and other dendromass. The cultivation of fast growing energy poplar on agricultural land is an alternative mainly in non-forested areas of Slovakia on the low quality soils (5-9) with high ground water level.

The incidence of diseases and pests on energy trees in his writings indicate Pei (2005), Tomašovič et al. (2006), Pei and Shang (2005), and Pei and Yuan (2005). Liesebach and Zaspel, (2005) address the research of genetic diversity of rust *Melampsora* for of energy crops. Tothová (2012) examined the impact of selected biotic factors on production process of different varieties of fast-growing trees.

The aim of this paper is to evaluate the impact of drier soil and climatic conditions of south-western Slovakia and different planting methods of four Italian poplar hybrids and their production and energy indicators.

MATERIAL AND METHODS

The research was carried out in 2009-2011 on the land belonging to Slovak University of Agriculture in Nitra situated in cadastral area of Kolíňany village. The research site is located at an altitude of 180 m above sea level and belongs to a warm, very dry and lowland climate region. The average annual temperature is 9.9°C and average long-term (1951-2000) annual rainfall is 547.6 mm. Soil in the research site is moderate (loam), fluvisol, pH 7.26 and humus content 1.8 %.

Four hybrids (Monviso, Pegaso, AF-2 and Sirio) of poplar originating from Italian breeding program were incorporated in the research.

Characteristics of the poplar hybrids:

Monviso: *Populus* × *generosa* × *Populus nigra*, origin: controlled hybrid, mother: P*opulus* × *generosa* [*P. deltoides* 583 (Iowa – USA) × *P. trichocarpa* 196 (Oregon – USA)], father: *Populus nigra* 715-86 [*P. nigra* 12 (Piedmont – Italy) × *P. nigra* 7 (Umbria – Italy)], sex: female.
AF-2: *Populus* × *canadensis*, origin: controlled hybrid, mother: *Populus deltoides* 145-86 (Illinois – USA), father: *Populus nigra* 40 (Piedmont – Italy), sex: female.
SIRIO: *Populus deltoides* × *Populus* × *canadensis*, origin: controlled hybrid, mother: *Populus deltoides* 266 (Tennessee – USA), father: *Populus* × *canadensis* 4-85 [*P. deltoides* 1095 (Illinois – USA) × *P. nigra* 666 (Tuscany – Italy)], sex: male.
PEGASO: *Populus* × *generosa* × *Populus nigra*, origin: controlled hybrid, mother: *Populus* × *generosa* [*P. deltoides* 80-16 (Iowa – USA) × *P. trichocarpa* 84-19 (Oregon – USA)], father: *Populus nigra* 4 (Piedmont – Italy), sex: male

Planting of poplars was performed in double-rows and two methods of planting were used. The first method consisted of planting of 0.2 m long cuttings from one-year old shoots (25 mm in diameter) into the ground leaving 30 mm of cuttings above the soil surface. In the second method, the 0.2 m long cuttings were completely pushed into the soil so that non of it was sticking up above the soil surface. Distance between the double-rows was 2.0 m, within the row 1.0 m and distance of the planted cuttings in a row was 0.75 m. This provides 8.889 plants ha^{-1}. Samples of the poplar hybrids were oven-dried at 105°C in order to estimate the dry matter yield. Methodological procedures for determining production and energy indicators were as follows:

- The percentage of rooted cuttings was surveyed 30 days after planting. It indicates the percentage of well-rooted cutting from the total number of planted cuttings,
- Number of shoots produced by individuals (cuttings) was determined 60 days after planting,
- In the beginning of the second growing year, 30 days after cutback, the number of new shoots, depending on the initial number of shoots produced on the cuttings in the first growing year was determined,
- The number of living shoots and shoot mortality were observed also in the third growing period in order to determine the loss of shoots for the entire three-year growing period, The measurement of the shoot length and thickness was carried out in 30 day intervals during the second and third growing period,
- The occurrence of weeds, diseases and pests was observed in 30 day intervals throughout the whole research period,
- The assessment of the biomass yields was performed at the end of each growing year. The energy value of biomass was determined at the end of the third growing year,
- The statistical evaluation of the observed production and energy indicators was done by single-factor analysis of variance (ANOVA) at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

The research during individual growing periods was carried out under different climatic conditions. In 2009, at the time of the field trials establishment (April), the average air temperature was 14.9°C, which gradually reached on average 21.7 and 21.4°C in July and August respectively. Total atmospheric precipitation was 571.3 mm during 2009, which is 23.7 mm above the long-term average. The second growing year (2010) was extreme from the precipitation amount point of view. The rainfall reached 860.2 mm, which exceeds the long-term average by 312.6 mm. The most rain fell in May (158 mm) and June (131 mm). The average temperature reached its peak in July (22.9°C). Compared to the second growing year (2010), which was extremely rich in rainfall, the total precipitation in the third growing year (2011) was only 420.4 mm. It is 127.1 mm below the long-term average. The maximum amount of precipitation fell in June (99.6 mm). The percentage of well-rooted cuttings after the planting is given in Tab. 1.

Tab. 1: Percentage of well-rooted cuttings of the observed poplar hybrids.

Clone	Percentage of well-rooted cuttings	
	First planting method	Second planting method
Monviso	66.67	76.67
AF-2	83.33	70.00
Pegaso	80.00	63.33
Sirio	70.00	60.00

Tab. 1 shows that the percentage of rooted cuttings is relatively low in individual poplar hybrids, especially in the second planting method. We assume that this was due to the longer period between the preparation of cuttings for planting and their planting, which took 5 days and thus could seriously affect the viability of cuttings and their rooting ability. Non-rooted cuttings were replaced by newly planted ones. Low percentage of rooted cuttings observed also Trnka et al. (2008) in *Populus nigra* clon J-104 ranging from 39.9 to 73.1 %. Low rooting percentage in the first year after planting of some poplar hybrids, due to poorer ability to root in heavy clay loam soils state Laureysens et al. (2004). Francis et al. (2005) attribute high mortality of planted poplar cuttings also to the lack of oxygen in soil in case of waterlogged soils.

The average number of shoots, produced on one planted cutting ranged from 1.00 (clone Sirio in both planting methods) to 1.63 shoots (clone Pegaso in the second planting method). However, cuttings with one shoot were dominant, less cuttings produced two or more shoots. The impact of planting method on the number of produced shoots as well as differences among individual hybrids was not statistically confirmed. The average number of shoots produced on the planted cuttings is given in Tab. 2.

Tab. 2: The average number of shoots produced on the planted cuttings of individual poplar hybrids in different planting methods.

Clone	Number of shoots	
	First planting method	Second planting method
Monviso	1.40	1.19
AF-2	1.08	1.10
Pegaso	1.17	1.63
Sirio	1.00	1.00

Fig. 1 shows the percentage of individuals in different hybrids and planting methods with one or more shoots in the first growing year.

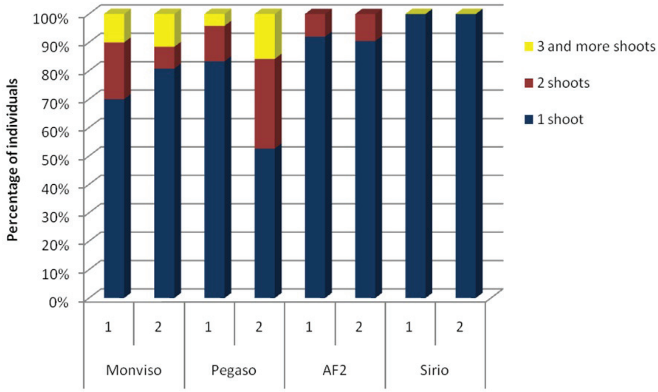

Fig. 1: Percentage of individuals in different hybrids and planting methods with one or more shoots in the first year.

Shoot formation was observed after the cut-back at the beginning of the second growing year, depending on the initial number of shoots and planting method. After the cut-back, the number of shoots created on originally one-shoot individuals in the first growing period ranged from 6.2 (clone Sirio in the first planting method) to 8.14 shoots (clone Pegaso in the first planting method) and 9.67 shoots (clone AF-2 in the first planting method) to 12.00 shoots (clone Pegaso in the first planting method) on originally two-shoot individuals in the first growing period. Laureysens et al. (2004) observed formation of 2-10 shoots on one poplar individual after the cutback. The impact of the original number of shoots on the shoot formation after the cut-back was observed, however the impact of the planting method and individual hybrids was not statistically confirmed. The average number of shoots formed after the cut-back is shown in Fig. 2.

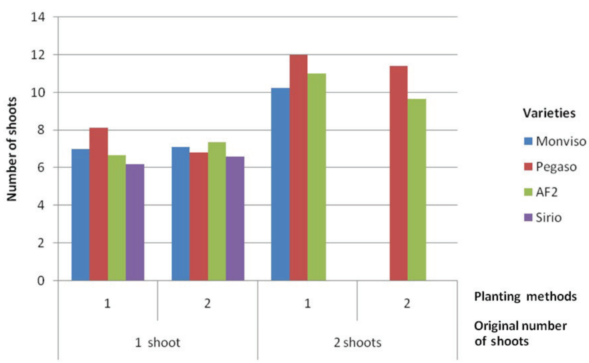

Fig. 2: The average number of shoots formed after the cut-back of one-year old shoots, depending on the original number of shoots and the planting method.

Similarly to willows, the studied poplar hybrids also showed characteristic gradual dying off (mortality) of shoots. As mentioned above, at the beginning of the second growing year, the observed hybrids created up to 12 shoots per individual. Two years after the cut-back (in the third growing period) it was only 2.6 to 4.6 live shoots. It means that the shoot mortality (from the original number of shoots formed after the cut-back) represents 63-72 % (Monviso), 54-60 % (Pegaso), 47.9-48.3 % (AF-2), and 48-61 % (Sirio) (Fig. 3).

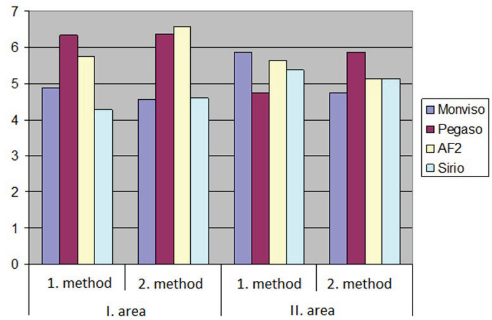

Fig. 3: The average number of live shoots growing in the third year (two years after the cut-back) on the studied poplar hybrids.

Growth dynamics of individual poplar hybrids was evaluated at the end of the third growing year (two years after the cut back). The data on the shoot thickness and height are shown in Figs. 4 and 5.

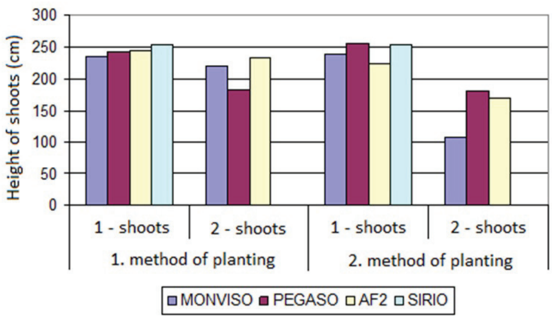

Fig. 4: Average height of shoots of different poplar hybrids at the end of the third year.

The assessment of the average and maximum shoot heights in the third year shows that shoot heights of clone Monviso ranged from 415.4 to 480.6 cm, with the maximum height of 715.0 cm. Shoot heights of clone Pegaso ranged from 337.0 to 369.0 cm, with the maximum height of 650.0 cm. Shoot heights of clone AF-2 ranged from 393.0 to 417.0 cm with the maximum height of 722 cm. Clone Sirio produced the highest shoots ranging from 442.0 to 462.0 cm, with the maximum height of 732.0 cm. Compared with the previous year, the increase of the average shoot height in 2011 was 1.3 to 1.7 times higher than the average height in 2010 and the increase of the maximum shoot heights was 1.4 to 1.5 times higher than the maximum height in 2010.

Statistical evaluation, however, did not show significant differences in the shoot heights among the hybrids and planting methods.

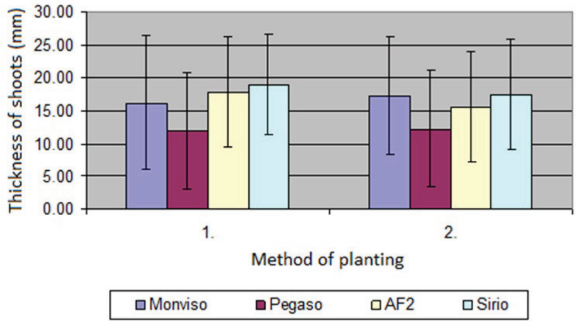

Fig. 5: Average thickness of shoots of individual poplars hybrids at the end of the third year.

Similarly to the shoot height, there were no statistically significant differences shown at the shoot thicknesses among the hybrids and planting methods. The average values of the thickness of shoots were as follows. The shoot thickness ranged from 25.1 mm to 30.9 mm with the maximum thickness of 55.2 mm in clone Monviso, from 20.5 mm to 22.1 mm with the maximum thickness of 54.4 mm in clone Pegaso, from 24.0 mm to 25.5 mm with the maximum thickness of 56.3 mm in clone AF-2, and from 29.0 mm to 31.3 mm with the maximum thickness of 59.0 mm shoot in clone Sirio.

Similarly to the shoot height, the highest values were provided by clone Sirio. There was 1.4 to 1.7 fold increase in the average and maximum shoot thickness in the third year compared with the previous year (2010). Biomass production of the poplars hybrids is shown in Tab. 3.

Tab. 3: Biomass production of different poplar hybrids in the third growing year (2011).

Clone	Planting method	Average % of dry matter	Average dry weight of 1 plant (kg)	Maximum dry weight of 1 plant (kg)	Dry matter yield ($t.ha^{-1}$)
Monviso	1	41.33	3.98	5.93	35.40
	2	41.33	2.50	3.30	22.25
AF-2	1	40.91	3.45	3.96	30.67
	2	40.91	2.55	3.14	22.71
Pegaso	1	40.84	2.15	4.70	19.12
	2	40.84	2.03	2.85	18.06
Sirio	1	41.76	3.42	5.09	30.42
	2	41.76	3.65	6.66	29.80

The assessment of the obtained biomass yields of different hybrids shows that the highest biomass yields were achieved in the first planting method in all hybrids. The highest yield of dry biomass converted to 8889 plants ha^{-1} was achieved by clone Monviso in the first planting method (35.40 $t.ha^{-1}$) and the lowest by clone Pegaso (19.12 $t.ha^{-1}$). Very low yields of dry biomass in Pegaso were obtained also due to poplar cancer (*Dothichiza populea*) that attacked the clone during the growing period. According to Dawson (2007) the threshold of economic efficiency of poplar growing is 10 t.ha^{-1} year. Our results indicate that only clone Pegaso was under this threshold. Biomass production of poplars, according to Sixto et al. (2010), is significantly affected by the site conditions like soil fertility, climate conditions and water availability. Chemical and energy analysis of biomass is shown in Tab. 4.

Tab. 4: Chemical and energy analysis of biomass of the observed poplar hybrids.

Chemical and energy indicator	**Symbol**	**Unit**	**The hybrids of poplars**			
			Monviso	**AF-2**	**Pegaso**	**Sirio**
Ash	A (d)	%	2.57	2.62	2.53	2.58
Elemental analysis	C t (d)	%	49.98	50.52	50.62	50.72
	H t (d)	%	6.67	6.85	6.81	6.30
	N (d)	%	1.12	1.13	1.08	1.10
Total sulfur	S total. (d)	%	0.056	0.050	0.052	0.053
Silicon	Si (d)	%	0.008	0.009	0.007	0.007
Combustion heat	Qs (d)	MJ.kg^{-1}	19.51	19.58	19.67	19.62
Caloric value	Qi (d)	MJ.kg^{-1}	18.65	18.17	18.27	18.90
Heating value	Qi (r)	MJ.kg^{-1}	17.52	17.25	17.39	17.40
Chlorine	Cl (d)	%	0.020	0.020	0.020	0.020

Tab. 4 shows that the studied chemical and energy parameters among the hybrids are not significantly different. Poplar stands were partially attacked by pests and diseases. The most widespread disease was rust (*Melampsora larici-populina*). Pei et al. (2007), similarly to our results, note that leaf rust caused by *Melampsora larici-populina* belongs to the most serious poplar diseases. There were also signs of poplar cancer (*Dothichiza populea* (anam. *Cryptodiaporthe populea*)) observed on clone Pegaso. Significant pests attacking some poplar hybrids were *Chrysomela* (*Melasoma*) *populi* damaging the foliage and *Tipula paludosa*. Dawson (2007) recommends, in order to minimize the occurrence of pests and diseases, to grow several hybrids within one plantation. According to Milovanović et al. (2011) the resistance against diseases is affected also by the total plant condition because the occurrence of some diseases can be caused by adverse weather and soil factors. It had been shown that the disease resistance of hybrids declared by breeder does not have to hold true in different climate conditions.

CONCLUSIONS

The research carried out during the three growing periods took place in different temperature and moisture conditions. Especially the second growing year (2010) can be considered as extreme due to the high amount of precipitations. The total precipitation was 860.2 mm, which exceeded the long-term average by 312.6 mm.

The percentage of well-rooted cuttings was relatively low, especially in the second planting method. This was mainly due to a longer transportation period of the planting material from the supplier that could significantly affect the viability of the cuttings.

The number of shoots produced per planted cuttings ranged from 1.0 to 1.6. Individuals with one shoot dominated over the cuttings that produced two or more shoots.

In the second year after the cut back, the individuals of the studied hybrids produced on average 6 to 12 shoots. A certain impact of the original number of shoots (produced after planting) on the number of shoots produced after the cut back was observed.

A significant mortality of shoots was observed in the third growing year. While the studied hybrids according to the different planting methods produced up to 12 shoots per individual in the second growing year, there were only 2.6 to 4.6 shoots per individual in the third year.

There was a significant increase in the average length and thickness of shoots in the third growing year compared to the previous two vegetation years. The shoot length was 1.3 to 1.7 times higher than the average shoot length measured in the previous year. The thickness of shoots was 1.4 to 1.7 times higher compared to the previous growing year.

The highest yield of dry biomass in the third growing year was achieved by clone Monviso (35.40 t.ha^{-1}) in the first planting method. Clone Pegaso provided the lowest values (18.06 t.ha^{-1}) in the second method of planting.

The studied chemical and energy parameters among the individual hybrids were not significantly different.

The occurrence of diseases and pests negatively affected photosynthetic potential of the poplar hybrids.

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