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COMPARISON OF PRODUCTION PARAMETERS OF WILLOW (*SALIX* spp.) AND POPLAR (*POPULUS* spp.) VARIETIES IN THE LAST YEAR OF THE FIRST FOUR-YEAR HARVEST CYCLE

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ABSTRACT

The research carried out in the fourth year of the first rotation cycle of willow and poplar aimed at evaluation of production parameters. There were four varieties of willow (*Salix* spp.) and four varieties of poplar (*Populus* spp.) included in the research. The studied willow varieties were Inger, Express, Klara and Dimitrios, and the poplar varieties were Monviso, Pegaso, AF-02 and Sirio. The research took place in the field trial at a farm holding belonging to Slovak University of Agriculture in Kolíňany. The site is located at an altitude of 180 m above sea level and belongs to temperate, very dry and lowland climatic region. The production parameters observed on all the varieties of willows and poplars were the number of shoots per individual, length and diameter of shoots, number of shoots in various categories of shoot length and diameter, above ground biomass yield at harvest moisture content and in dry matter and annual production of above ground biomass in dry matter. The results of the individual production parameters show that the number of shoots per individuals were higher in willow varieties. The average length of willow and poplar shoots was not significantly different. The willow and poplar varieties with the highest average number of shoots had the lowest average shoot lengths. The varieties with the lowest average number of shoots had the highest average shoot diameters. The highest yield of dry matter of poplar was achieved by the variety Monviso (87.16 $t.ha^{-1}$), in willows it was the variety Express (94.50 $t.ha^{-1}$). All willow and poplar varieties exceeded the economic production threshold of 10-12 $t.ha^{-1}$ in dry matter. The dry matter of willow varieties ranged from 17.92 to 23.64 $t.ha^{-1}$ $year^{-1}$ and the dry matter of poplar varieties ranged from 16.85 to 21.79 $t.ha^{-1}$ $year^{-1}$.

KEYWORDS: Production parameter, biomass yield, shoot, economic threshold for the cultivation of energy plants.

INTRODUCTION

For the past eight years (since 2006) Slovak University of Agriculture in Nitra (SUA) has carried out the research on several research sites focused on the production potential of different varieties of energy plants genus *Salix* and *Populus*. It has been showed that the suitability of a particular type of energy woody crops used for intensive growing in drier soil-climatic conditions of south-western Slovakia is dependent on an adaptability and demands of individual species on the natural environment, either soil-climatic or to a lesser extent, hydrologic. The research has shown that there are only few varieties suitable for commercial cultivation in the soil-climatic conditions of the sites, mainly due to low resistance to fungal diseases especially against rust (*Melampsora* spp.). According to Samson et al. (1999), willows are more suitable for commercial cultivation than poplars in terms of productivity, because they achieve higher biomass yields at lower costs. In order to achieve high willow biomass yields, Hall (2003) considers the best sites for willow growing such, where soils are saturated with water or are periodically flooded. On the contrary, poplars do not grow well on such soils, but they can be grown on drier soils where the ground water is available at a depth of 1-2 m. This requirement was met in the research site in Kolíňany.

There are several papers comparing production parameters of different varieties of willow and poplar. Gyurica (2010) reported production parameters for different willow varieties at the end of the first three-year harvest cycle. Trnka (2009) observed production parameters of six-year old stand of willow and poplar. Németh (2010) compared the production potential of the two-year old stand of willow and poplar. Tóthová (2012) evaluated the selected production indicators of different varieties of willow and poplar in the third year after planting. Other works by domestic authors such as Daniel and Medvecký (2010), Demo et al. (2011), Bako and Tóthová (2010), Hauptvogl (2011), Fazekaš (2011), Skladan (2010) and Habán et al. (2013) discuss the issue of the production of energy performance of different varieties of the genus *Salix* and *Populus* grown in the northern and southern regions of Slovakia. Jureková and Marišová (2008), Jureková et al. (2008,), Jureková and Dražič (2011) deal with the issue of environmental limits, but also with legal aspects of the energy plant cultivation in Slovakia.

The aim of the paper is to provide information about the cultivation of energy crops of the genus *Salix* and *Populus*, production efficiency of the studied commercial willow and poplar varieties and recommend a variety suitable for large scale plantation growing in the soil-climatic conditions of south-western Slovakia.

MATERIAL AND METHODS

The research aimed at comparison of the production characteristics of four varieties of willow (*Salix* spp.) and poplar (*Populus* spp.) grown in drier soil-climatic conditions of south-western Slovakia took place in the field trial in Kolíňany. The research site is located at an altitude of 180 m above the sea level. It belongs to the temperate, very dry and lowland climatic region. The average annual temperature is 9.9°C. The period with the average temperatures of more than or equal to 10°C begins on April 15th and lasts until October 15th, which is 184 days. The long-term (1951-2000) average annual rainfall is 547.6 mm (Špánik and Šiška 2008). The soil in the research site is moderate (loam) fluvisol with an average pH of 7.26 and humus content of 1.8 %.

The production parameters of energy willow (*Salix* spp.) were observed on the following varieties:

Inger: *Salix triandra×S.viminalis*
Klara: *(S. viminalis × S. dasyclados) × S. viminalis × (S. schwerinii × S.viminalis)*
Dimitrios: *(S. schwerinii×S. viminalis) ×S.aegyptiaca*
Express: *S.alba L.*

The varieties Inger, Klara and Dimitrios come from Swedish breeding program, the variety Express comes from Hungarian breeding program.

The production parameters of poplar (*Populus* spp.) were observed on the following varieties:
Monviso: *Populus×generosa× P.nigra*
Pegaso–*P.×generosa× P.nigra*
AF-2 –*P.×canadensis,*
Sirio–*P. deltoides×Populus×canadensis*

The following production parameters were observed both on willow and poplar varieties:

- Number of shoots per individuals,
- Length of shoots in m,
- Shoot diameter in mm,
- Number of shoots per individuals in different willow varieties divided into various categories of length and diameter sizes,
- Number of shoots per individuals in different varieties of poplar divided into various categories of length and diameter sizes,
- Above-ground biomass yields of the willow varieties in kg,
- Above-ground biomass yields of the willows varieties in $t.ha^{-1}$ at harvest moisture content and in dry matter
- Above-ground biomass yields of the poplar varieties in kg,
- Above-ground biomass yields of the poplar in $t.ha^{-1}$ at harvest moisture content and in dry matter

Single-factor analysis of variance (ANOVA) at significance level $\alpha = 0.05$ was used in order to determine a statistical significance among the production parameters of the studied willow and poplar varieties.

RESULTS AND DISCUSSION

The results of the observed production parameters of the studied willow and poplar varieties are shown in Tabs. 1 and 2. The average number of shoots of the poplar varieties (Tab. 1) ranged from 5.00 (AF-02) to 6.66 (Pegaso). The average shoot length was similar in three varieties (Monviso, Pegaso and Sirio) ranging from 4.28 to 4.88 m. The variety AF-02 had significantly higher values of the shoot length (5.25 m). The average shoot diameter in three varieties (Monviso, Pegaso and AF-02) ranged from 26.23 to 28.67 mm. This parameter was significantly higher in the variety Sirio (32.72 mm). As can be seen in Tab. 1, the variety with the highest average number of shoots (Pegaso) has the lowest values of shoot length and diameter. On the contrary, the variety with the lowest average number of shoots has the highest values of the average shoot diameter.

Trnka (2009) observed the shoot length of the eight six-year poplar clones ranging from 5.6 to 11.0 m and the shoot diameter ranging from 40 to 100 mm.

The average number of shoots is significantly higher in the willow varieties compared with the poplar varieties, ranging from 7.00 (Express) to 10.33 m (Inger). The average shoot length of willow varieties was not significantly different from the poplar varieties, ranging from 3.66

(Express) to 5.58 (Klara). The average shoot diameter of the willow varieties ranged from 21.10 (Dimitrios) to 24.81 mm (Express).

Gyurica (2010) states that a three-year old stand of the variety Inger had 13 to 17 of shoots per individual, the shoot length varied from 5.3 to 5.4 m and the shoot diameter varied from 12.0 to 13.8 mm. According to Trnka (2009) the average shoot length of a six-year old stand of 15 willow clones ranged from 4.3 to 9.6 m and the shoot diameter ranged from 30 to 80 mm.

Tab. 1: Selected production parameters of the poplar varieties in the fourth growing year (2012).

Varieties	Replicate	Production parameters				
		Number of shoots	Average lenght of shoots in the individual replicates (m)	Average lenght of shoots of the studied varieties (m)	Average shoot diameter in the individual replicates (mm)	Average shoot diameter of the studied varieties (mm)
Monviso	1	5	4.52	4.34	28.98	28.67
	2	6	4.14		26.06	
	3	5	4.37		30.98	
Pegaso	1	4	4.65	4.28	28.45	26.23
	2	9	3.52		20.50	
	3	7	4.68		30.11	
AF-2	1	5	4.42	5.25	30.96	27.90
	2	3	3.95		25.33	
	3	7	4.40		27.41	
Sirio	1	4	4.93	4.88	32.32	32.72
	2	5	4.63		30.34	
	3	4	5.08		35.50	

Tab. 2: Selected production parameters of the willow varieties in the fourth growing year (2012).

Varieties	Replicate	Production parameters				
		Number of shoots	Average lenght of shoots in the individual replicates (m)	Average lenght of shoots of the studied varieties (m)	Average shoot diameter in the individual replicates (mm)	Average shoot diameter of the studied varieties (mm)
Inger	1	11	4.45	4.34	21.93	21.95
	2	11	4.61		21.32	
	3	9	3.97		22.62	
Express	1	7	3.44	3.66	23.00	24.81
	2	6	4.44		31.71	
	3	8	3.10		19.72	
Klara	1	110	5.64	5.58	26.46	24.74
	2	8	6.11		26.82	
	3	11	5.04		20.96	
Dimitrios	1	11	4.45	4.46	12.82	21.10
	2	8	4.67		23.12	
	3	9	4.26		27.36	

The above-ground biomass yields of poplar and willow varieties are shown in Tabs. 3 and 4. The average biomass yield per one plant of the studied poplar varieties (Tab. 3) ranged from 15.83 (AF-02) to 21.16 kg (Monviso). The total average biomass yield at the harvest moisture content ranged from 140.74 (AF-02) to 188.14 t.ha^{-1} (Monviso). The dry matter content ranged from 44.76 to 47.91 %. Thus the average yield of dry matter ranged from 67.42 (AF-02) to 87.16 t.ha^{-1} (Monviso).

Trnka (2009) states that the average dry matter yield of eight six-year old poplar clones ranged from 70.0 to 127.0 t.ha^{-1}. The annual biomass production of poplars grown in a two-year cycle observed by Németh (2010) was 22.0 t.ha^{-1}. Tóthová (2012) reports the dry matter yield of poplar grown in three-year cycle ranging from 18.06 to 35.40 t.ha^{-1}.

The average biomass yield of the studied willow varieties (Tab. 4) ranged from 15.76 (Inger) to 21.35 kg (Express). Only Express provided similar biomass yields as the best poplar variety (Monviso). Other willow varieties provided significantly lower biomass yields than the poplar varieties. The argument made by Samson et al. (1999) that willows, in terms of productivity, are more efficient than poplars cannot be generalized. The biomass yield of the studied willow varieties harvested at moisture content of 48.66 to 50.16 % ranged from 140.14 (Inger) to 189.80 t.ha^{-1} (Express). The biomass yield of dry matter ranged from 71.69 (Inger) to 94.59 t.ha^{-1} (Express). As shown in Tab. 4, the highest biomass yield of the dry matter of all studied poplar and willow varieties was achieved by willow variety Express. The biomass yield observed by Gyurica (2010) at the end of the three-year harvest cycle of the variety Inger (harvest moisture 46.27 %) was 124.47 t.ha^{-1}, which is slightly lower yield compared to our results achieved at the end of the four-year cycle. Trnka (2009) observed the dry matter yield of 15 willow clones at the end of the six-year growing cycle ranging from 44.0 to 104.0 t.ha^{-1}. Németh (2010) compares the annual production potential of poplars and willows grown in a two-year cycle. The annual biomass production of poplars was 22.0 t.ha^{-1} and the willow variety Express provided 35.0 t.ha^{-1}. The dry matter yield of the varieties Inger and Express, grown in three-year cycle, ranged from 32.67 to 35.85 t.ha^{-1} (Inger) and 31.55 to 33.92 t.ha^{-1} (Express) (Tóthová 2012).

Tab. 3: Biomass yields of the poplar varieties in the fourth growing year (2012).

Varieties	Replicate	Biomass yield						
		Average biomass yield per individual plants (kg)	Average biomass yield of the studied varieties (kg)	Average biomass yield of individual plants at harvest moisture (t.ha^{-1})	Avarage biomass yield of the studied varieties a harvest moisture (t.ha^{-1})	Content of dry matter(%)	Average biomass yieldof the dry matterof the individual plants (t.ha^{-1})	Average biomass yield of the dry matter of the studied varieties (t.ha^{-1})
Monviso	1	18.60	21.16	165.33	188.14	46.33	76.59	87.16
	2	17.80		158.22			73.30	
	3	27.10		240.89			111.60	
Pegaso	1	15.60	18.83	138.66	167.40	45.94	63.70	76.90
	2	16.40		145.77			66.96	
	3	24.50		217.75			100.04	
AF-2	1	15.90	15.83	141.33	140.74	47.91	67.71	67.42
	2	9.90		88.00			42.16	
	3	21.70		192.89			92.41	
Sirio	1	16.80	19.76	149.33	175.70	44.76	66.84	78.64
	2	20.00		177.78			79.57	
	3	22.501		200.00			89.52	

Tab. 4: Biomass yields of the willow varieties in the fourth growing year (2012).

Varieties	Replicate	Biomass yield						
		Average biomass yield per individual plants (kg)	Average biomass yield of the studied varieties (kg)	Average biomass yield of individual plants at harvest moisture ($t.ha^{-1}$)	Avarage biomass yield of the studied varieties a harvest moisture ($t.ha^{-1}$)	Content of dry matter (%)	Average biomass yield of the dry matter of the individual plants ($t.ha^{-1}$)	Average biomass yield of the dry matter of the studied varieties ($t.ha^{-1}$)
Inger	1	16.80	15.76	149.33	140.14	51.16	76.39	71.69
	2	16.10		143.11			73.21	
	3	14.40		128.00			65.48	
Express	1	23.92	21.35	212.62	189.80	49.84	105.96	94.59
	2	23.94		212.80			106.05	
	3	16.20		144.00			71.76	
Klara	1	17.80	16.56	158.22	147.25	50.85	80.45	74.87
	2	16.50		146.66			74.57	
	3	15.40		136.89			69.60	
Dimitrios	1	17.20	16.30	152.89	144.88	51.34	78.49	74.38
	2	14.80		131.55			67.53	
	3	16.90		150.22			77.12	

Tabs. 5-12 show the results of the shoot formation in different poplar and willow varieties at the end of the four-year harvest cycle divided into various length and diameter size groups.

Tabs. 5 and 6 present the shoot formation of the individual poplar and willow varieties divided into different length categories. The results show that the biggest amount of shoots can be found in the length category up to 5 m in the studied varieties of both species. A few shoots exceeded the length of more than 8 and/or 9 m. The majority of poplar and willow shoots can be found in the category of shoots with diameter of up to 40 mm (Tabs. 7, 8). Only a small number of shoots had the diameter of more than 40 mm. Tabs. 9 and 10 show shoot lengths and diameters of the individual willow varieties. The longest shoots were provided by the variety Klara (560.2 cm) and the thickest shoots by the varieties Express (24.8 mm) and Klara (24.7 mm). The longest poplar shoots (Tabs. 11 and 12) were created by the variety Sirio (488.2 cm) and the thickest shoots also by the variety Sirio (32.7 mm).

From a commercial point of view, the biomass yield is the crucial parameter of the of energy crops cultivation. The economic threshold for willows and poplars stated by Lindegard et al. (2001) is 10-12 $t.ha^{-1}$ $year^{-1}$ of dry matter. Also Buchholz and Volk (2011) consider 12 t. ha^{-1} $year^{-1}$ of dry matter as economically affordable yield in conditions of USA. According to their model scenario, an increase of yield by 2 $t.ha^{-1}$ $year^{-1}$ (by using new, more productive varieties or improving the growing technology) will increase the rate of return by 5.1 to 8.3 %. In our study, all poplar and willow varieties exceeded this annual economic threshold. The annual yield of dry matter of poplar varieties reached values ranging from 16.85 (AF-02) to 21.79 $t.ha^{-1}$ (Monviso). The annual dry matter yield of willow varieties ranged from 17.92 (Inger) to 23.64 $t.ha^{-1}$ (Express). According to these results, all studied willow and poplar varieties are suitable for a large-scale commercial growing.

Tab. 5: Shoot formation of the studied poplar varieties by the individual shoot length categories (m) in the fourth growing year (2012).

Varieties	Replicate																														
	1									2										3											
	Categories of the length sizes (m)																														
	Number of shoots	< 2m	> 2m	> 3m	> 4m	> 5m	> 6m	> 7m	> 8m	Number of shoots	< 2m	> 2m	> 3m	> 4m	> 5m	> 6m	> 7m	> 8m	Number of shoots	< 2m	> 2m	> 3m	> 4m	> 5m	> 6m	> 7m	> 8m	> 9m			
	Number of shoots in the correspondent length category																														
Monviso	5	2	0	1	0	0	0	1	1	6	2	0	1	1	1	0	0	1	5	1	0	1	2	0	0	0	0	1			
Pegaso	4	0	1	2	0	0	0	0	1	9	2	2	4	0	0	0	0	1	7	0	3	0	1	1	1	0	1	0			
AF-2	2	0	1	0	0	0	0	1	0	3	1	1	0	0	0	0	1	0	7	2	1	1	0	0	2	0	0	1			
Sirio	4	0	0	2	1	0	0	0	1	5	0	1	2	1	0	0	0	1	4	0	2	0	0	0	0	2	0	0			

Tab. 6: Shoot formation of the studied willow varieties by the individual shoot length categories (m) in the fourth growing year (2012).

Varieties	Replicate																														
	1									2										3											
	Categories of the length sizes (m)																														
	Number of shoots	< 2m	> 2m	> 3m	> 4m	> 5m	> 6m	> 7m	> 8m	Number of shoots	< 2m	> 2m	> 3m	> 4m	> 5m	> 6m	> 7m	> 8m	Number of shoots	< 2m	> 2m	> 3m	> 4m	> 5m	> 6m	> 7m					
	Number of shoots in the correspondent length category																														
Inger	11	0	5	1	0	1	1	3	0	11	0	4	1	1	1	1	3	0	9	0	4	0	2	0	0	3					
Express	7	3	2	0	0	0	0	1	1	6	1	1	1	0	2	0	0	1	8	4	2	0	0	1	0	1					
Klara	10	0	2	1	1	1	0	5	0	8	0	0	1	1	2	1	1	2	11	0	4	1	0	2	0	4					
Dimitrios	11	2	1	1	2	2	3	0	0	8	0	2	0	2	3	1	0	0	9	0	0	3	2	3	1	0					

Tab. 7: Shoot formation of the studied poplar varieties by the individual shoot diameter categories (m) in the fourth growing year (2012).

Varieties	Replicate																														
	1									2										3											
	Categories of the diameter sizes (mm)																														
	Number of shoots	< 10	> 10	> 20	> 30	> 40	> 50	> 60		Number of shoots	< 10	> 10	> 20	> 30	> 40	> 50	> 60	> 70	Number of shoots	< 10	> 10	> 20	> 30	> 40	> 50	> 60	> 70	> 80			
	Number of shoots in the correspondent length category																														
Monviso	5	2	1	0	0	1	0	1		6	2	12	2	0	0	0	1	0	5	1	1	2	0	0	0	0	0	1			
Pegaso	4	0	2	1	0	0	0	0		9	2	5	1	0	0	0	1	0	7	0	3	1	2	0	0	0	1	0			
AF-2	2	0	1	0	0	1	0	1		3	1	1	0	0	0	1	0	0	7	2	1	2	1	0	0	0	1	0			
Sirio	4	0	1	2	0	0	0	1		5	0	3	1	0	0	0	0	1	4	0	2	0	0	0	1	1	0	0			

Tab. 8: Shoot formation of the studied willow varieties by the individual shoot diameter categories (m) in the fourth growing year (2012).

Varieties	Replicate																														
	1									2										3											
	Categories of the diameter sizes (mm)																														
	Number of shoots	< 10	> 10	> 20	> 30	> 40	> 50	> 60	> 70	Number of shoots	< 10	> 10	> 20	> 30	> 40	> 50	> 60	> 70	Number of shootsv	< 10	> 10	> 20	> 30	> 40	> 50	> 60					
	Number of shoots in the correspondent length category																														
Inger	11	3	3	1	2	2	0	0	0	11	4	2	1	3	1	0	0	0	9	2	2	2	2	1	0	0					
Express	7	4	1	0	0	1	0	0	1	6	1	1	1	2	0	0	0	1	8	4	2	0	1	0	0	1					
Klara	10	1	2	2	5	0	0	0	0	8	0	3	2	3	0	0	0	0	11	3	2	3	2	1	0	0					
Dimitrios	11	4	5	2	0	0	0	0	0	8	2	1	3	2	0	0	0	0	9	1	1	3	3	1	0	0					

Tab. 9: Number and length of the shoots of the willow varieties in the fourth growing year (2012).

Varieties	Replicate	Number of shoots	Average shoot length (cm)												
			1	2	3	4	5	6	7	8	9	10	11	Average per replicate	Averagte per variety
Inger	1	11	745	730	700	660	510	320	280	260	250	223	219	445.1	431.8
	2	11	740	730	700	610	560	450	330	269	256	235	200	464.8	
	3	9	773	772	720	449	447	287	282	279	265			397.6	
Express	1	7	840	720	274	210	170	120	76					344.2	366.3
	2	6	820	580	510	300	280	174						444.0	
	3	8	795	583	240	220	185	163	151	150				310.8	
Klara	1	10	790	780	760	740	735	590	410	313	267	261		564.6	560.2
	2	8	820	810	780	610	530	510	490	343				611.6	
	3	11	796	795	794	776	554	548	369	268	236	210	205	504.6	
Dimitrios	1	11	620	610	610	570	560	490	480	370	216	194	175	445.0	446.3
	2	8	610	585	580	540	490	460	240	232				467.1	
	3	9	630	590	560	510	480	473	350	345	330			426.8	

Tab. 10: Number and diameter of the shoots of the willow varieties in the fourth growing year (2012).

Varieties	Replicate	Number of shoots	Average shoot diameter (mm 10^{-1})												
			1	2	3	4	5	6	7	8	9	10	11	Average per replicate	Averagte per variety
Inger	1	11	42.3	40.4	35.6	34.8	24.3	12.5	12.3	10.8	98.0	96.0	89.0	22.9	22.0
	2	11	40.9	35.4	33.3	33.0	26.9	18.7	12.2	95.0	92.0	82.0	73.0	2.3	
	3	9	42.2	36.1	36.0	27.0	20.4	13.1	10.4	93.0	91.0			2.6	
Express	1	7	70.6	49.1	12.7	91.0	88.0	54.0	53.0					2.0	24.8
	2	6	75.7	39.6	32.1	20.2	16.9	58.0						3.7	
	3	8	65.0	37.1	11.7	10.5	94.0	89.0	85.0	67.0				1.7	
Klara	1	110	36.9	36.9	35.4	34.3	32.4	24.5	22.6	18.4	13.3	99.0		26.5	24.7
	2	8	39.8	38.9	36.8	25.3	20.8	19.6	19.5	13.9				26.8	
	3	11	40.1	35.6	32.8	28.1	23.6	21.6	10.5	10.0	96.0	91.0	89.0	20.9	
Dimitrios	1	11	26.5	20.1	18.8	18.4	15.0	12.1	10.4	69.0	49.0	43.0	37.0	12.8	21.1
	2	8	36.9	31.7	28.3	28.2	22.1	19.5	95.0	88.0				23.1	
	3	9	41.5	38.4	35.6	32.4	28.9	28.0	21.6	10.1	98.0			27.4	

Tab. 11: Number and length of the shoots of the poplar varieties in the fourth growing year (2012).

Varieties	Replicate	Number of shoots	Average shoot length (cm)										
			1	2	3	4	5	6	7	8	9	Average per replicate	Averagte per variety
Monviso	1	5	860	710	360	178	152					452.0	434.5
	2	6	870	520	410	345	199	141				414.1	
	3	5	910	403	313	160						437.4	
Pegaso	1	4	850	390	340	281						465.2	428.7
	2	9	840	390	380	370	310	290	240	199	157	352.8	
	3	7	849	635	590	463	265	250	225			468.1	
AF-2	1	5	740	600	520	240	110					442.2	425.7
	2	3	780	280	125							395.0	
	3	7	901	619	618	354	203	195	190			440.0	
Sirio	1	4	850	410	380	333						493.2	488.2
	2	5	855	480	350	340	290					463.0	
	3	4	790	763	251	230						508.5	

Tab. 12: Number and diameter of the shoots of the poplar varieties in the fourth growing year (2012).

Varieties	Replicate	Number of shoots	Average shoot length (mm 10-1)										
			1	2	3	4	5	6	7	8	9	Average per replicate	Averagte per variety
Monviso	1	5	64.0	45.9	18.9	83.0	78.0					29.0	28.7
	2	6	68.5	29.5	23.3	19.2	92.0	67.0				26.0	
	3	5	82.6	23.9	21.1	17.7	96.0					31.0	
Pegaso	1	4	62.4	21.0	12.9							28.5	26.2
	2	9	65.0	21.0	19.7	17.9	17.6	13.7	12.4	97.0	75.0	20.5	
	3	7	74.2	38.7	34.9	25.5	14.6	12.4	10.5			30.1	
AF-2	1	5	44.6	41.5	37.3	21.6	98.0					31.0	27.9
	2	3	55.5	16.1	44.0							25.3	
	3	7	73.0	30.5	29.3	21.5	18.9	99.0	88.0			27.4	
Sirio	1	4	69.1	21.8	21.6	16.8						32.3	32.7
	2	5	72.5	26.0	19.9	18.3	15.0					30.3	
	3	4	61.2	51.9	15.4	13.5						35.5	

CONCLUSIONS

Following conclusions can be made from the evaluation of production characteristics of different varieties of willow (*Salix* spp.) and poplar (*Populus* spp.) observed at the last year of the first four-year harvest cycle:

- The number of shoots produced by the individual willow and poplar varieties was significantly different. The number of shoots of poplar varieties ranged from 5.0 (AF-02) to 6.6 (Pegaso). The number of shoots of willow varieties ranged from 7.0 (Express) to 10.3 (Inger).
- The average shoot length of poplar varieties was not significantly different from the average shoot length of willow varieties. The longest shoots of poplar were created by the variety AF-02 (5.25 m). The longest shoots of willow were achieved by the variety Klara (5.58 m).
- The varieties with the highest average number of shoots had the lowest average shoot lengths in both willows and poplars. The varieties with the lowest average number of shoots had the highest average shoot diameters.
- The average biomass yield of the poplar varieties at the harvest moisture content ranged from 140. 74 in (AF-02) to 188.14 $t.ha^{-1}$ (Monviso). The average yield of the dry matter, at the dry matter content of 44.76 to 47.91 %, ranged from 67.42 (AF-02) to 87.16 $t.ha^{-1}$ (Monviso).
- The average biomass yield of the studied willow varieties at the harvest moisture content ranged from 140.14 (Inger) to 189.80 $t.ha^{-1}$ (Express). The average yield of dry matter, at the dry matter content of 49.84 to 51.34 % ranged from 71.69 (Inger) to 94.59 $t.ha^{-1}$ (Express).
- The economic threshold for the cultivation of energy plants is around 10-12 $t.ha^{-1}$ $year^{-1}$ of dry matter. In our study, all willow and poplar varieties significantly exceeded this economic threshold. The annual dry matter production of the poplar varieties ranged from 16.85 (AF-02) to 21.79 $t.ha^{-1}$ (Monviso). The annual dry matter production of the willow varieties ranged from 17.92 (Inger) to 23.64 $t.ha^{-1}$ (Express). The results show that all the studied willow and poplar varieties are suitable for a large-scale commercial cultivation.

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