CULTIVATION OF FAST-GROWING WOODY PLANT BASKET WILLOW (*SALIX VIMINALIS* L.) AND THEIR BIOREMEDIAL ABILITIES WHILE FERTILIZED WITH WOOD ASH

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Abstract: *Energetic utilization of wood biomass obtained from fast-growing woody plants nowadays records more important capability. The article discusses the issue of research using wood ash as solid waste from the boiler while burning biomass and the intensification of short-rotation coppice basket willow – common osier (Salix viminalis L.) for energy use as a renewable energy source. Purpose of the article is to show the importance of basket willow (Salix viminalis L.) as short-rotation coppice with the emphasis of its production and remedial effects.*

Key words**:** *renewable energy resources (carriers), biomass, short-rotation trees, basket willow, common osier (Salix viminalis L.), wood ash words*

INTRODUCTION

Fast growing woody plantations are potential resources of biomass which is used for energy purposes. Biomass is a significant part of renewable energy resources. One of the main reasons of using of renewable energy resources is decreasing of human dependence on fossil fuels, which are non-renewable energy resources. Renewable energy resources thus represent the item of securing the sustainability in energy supplies and benefit the sustainable development (DEMO et al., 2007). One of these renewable energy resources is the biomass. It fulfills majority of benefits from all spectrum of renewable energy resources (HÚSKA et al., 2000; NIŇAJ – HÚSKA, 2005). In the spring of 1994, experiments to prove the possibility for cultivation of fast-growing varieties of basket willow – common osier (*Salix viminalis* L.) were carried out in Krivá research centre, located in the Orava region of the Slovak Republic. For this purpose, three varieties of willow bred at the Research Institute of Agriculture in Swale (Sweden), were used: ULV, ORM and RAPP (HABOVŠTIAK – DANIEL, 2001). The same varieties are tested in the conditions of warm agro-climatic region in Dolná Malanta, Nitra, Slovakia. They have been grown here continuously since 1996. Experiments are established on Experimental Base of the Slovak Uneversity of Agriculture in Nitra, Slovak Republic (OTEPKA – HABÁN, 2006).

By the cultivation of fast growing coppice with short rotation period, the nutrients for growing plants are taking off intensively, reducing their storages in the soil. Partial compensation might be mineral multicomponent fertilization, for which wood ash with the content of wide spectrum of macro and microelements can fit well. Specific problem is that this type of solid waste generated in the boilers does not contain nitrogen, which had been released into the air after the biomass was burned. The project, supported by the Slovak Research and Development Agency is carried out by cooperation between Intech Slovakia, Ltd. and Slovak University of Agriculture in Nitra.

MATERIAL AND METHODS

Methodology of the experiment with wood species basket willow – common osier *(Salix viminalis* L.) has a long-term design (25 years). Stand was established by planting in the

spring of 1996 (19th April). Planting material was originated from Swedish breeding (Swale); source was in Research Centre Krivá in the Orava region, the Slovak Republic (VÚTPaHP). Planted cuttings were done in length 0.20 m; thickness from 10 to 20 mm. Forecrop was *Amaranthus* sp. Soil preparation was done by plowing to the depth of 30 cm, dragging, harrowing. Planting method: manually by hand. Treatment during the vegetation period is aimed to regulation of harmful factors (weeds, pests and diseases) and to maintain the status and condition of the crop stand.

Total cultivation area is approximately 648 m^2; area of individual plots (variants) is 108 m^2; total number of tested plots is 6; identification of plots: ORM/A, ORM/B, ULV/A, ULV/B, RAPP/A RAPP/B. Cultivated varieties: ORM, ULV, RAPP. Design of experiment: A – Double row planting with row distance = 0.5 m, alternated 1.25 m and 0.75 m between rows, B – plant spacing 0.5 x 0.75 m. The article includes results from a third four-year harvesting period of willow in the presented locality (2004 – 2007). In this plantation, the crop biomass forecasting of willow is based on mathematical-statistical model, published by Špánik and Čimo (2009). Wood ash was applied in the autumn period (October 2009) and in the spring period (March 2010) in doses of 1.0, 3.0 and 5.0 $t.ha^{-1}$, while the control area was left without application of wood ash. Size of each area is: 2 x 162 m^2, i.e. 324 m^2.

The biomass samples of *Salix viminalis* were taken in autumn period prior the leaf cast and the application of wood ash for analysis of the parameters: N_t, P, K, Ca, Mg, Mn, Zn, Cu, Fe, Na, S, Pb, Cd, Ag, As, pH and content of dry matter. Soil samples were taken according to the same experimental design in autumn and spring terms. The analysis of soil samples were orientated to: N_{an}, N, P, K, Mn, Zn, Cu, Fe, Ca, Mg, Na, Pb, Hg, Cd, As, pH, content of humus and dry matter.

RESULTS AND DISCUSSIONS

Results from laboratory analysis of plant biomass obtained in growing seasons 2009 and 2010 according to the methodology of basket willow (*Salix viminalis* L.) plantation design are given in Table 1. Results of soil samples taken in the plantation during the same two seasons are presented in Table 2.

Table 1 (a, b):
Results of laboratory analysis of the basket willow (*Salix viminalis* L.) above ground biomass in $mg.kg^{-1}$.

Year	Parameter	N	P	K	Ca	Mg	Na
2009	Average	17756.3	1915.0	5750.0	18213.0	3357.2	832.1
	Standard deviation	2063.9	155.7	1581.1	3684.9	561.1	134.2
2010	Average	14883.5	2159.2	7104.2	16187.9	2123.0	288.3
	Standard deviation	1132.5	257.5	1127.1	2215.8	497.8	50.8

Year	Parameter	S	Fe	Mn	Zn	Cu
2009	Average	2375.8	168.4	93.6	92.1	6.1
	Standard deviation	695.0	35.9	19.6	24.5	1.0
2010	Average	1969.2	*	*	*	*
	Standard deviation	480.8	*	*	*	*

*Note: Results are not delivered to the day of publication

Number of individual willow plants *(Salix viminalis* L.) per unit area depends on the plant spacing of 2.00 individual plants per m^2 (planting space A) or 2.67 individual plants per m^2 (planting space B). According to Šimala – Habovštiak (1995), well-managed willow grows in the first year up to the height of 2.0 – 3.0 m and after the fourth year cultivation; the crop is 7.0 m high. Individual crops with height of 7.0 m can be harvested. From this finding it is difficult to conclude whether the authors considered these data also in assessing of the third harvest period, but for the comparison of results we indicate, that one year after the second harvest, the indicated height of all three varieties was not reached: ORM (1.70 m), ULV (1.77 m) and also variety RAPP (1.45 m, see Table 1) was below the height of 2.00 m. Better average height of rods was always reached at the plant spacing B, i.e. the one where denser planting was applied. In subsequent years, the height of the vegetation ranged from 1.95 m (variety, RAPP/A, in the 10th year after planting) to 4.27 m (variety ULV/B, in the 12th year after planting), and as it can be seen in Table 1 in neither of cases, the height reached 7.0 m. This we attribute to the impact of harmful agents, soil characteristics of the experimental unit as well as to the weather conditions during the period of observation. When observing an average rod thickness, the values were measured according to the forestry parameters i.e. at a level of 1.3 m above the soil surface. Based on observations in the second harvest period, in this parameter we reached relatively low values, since in neither of case the value got over 20 mm. For ULV variety grown in the plant spacing B, the highest average rod thickness observed was 18.2 mm.

Table 2 (a, b):
Results from laboratory analysis of soil in basket willow (*Salix viminalis* L.) plantation in $mg.kg^{-1}$.

Year	Parameter	N_{an}	$N\text{-}NO^{3-}$	$N\text{-}NH^{4+}$	N	P	K
Autumn 2009	Average	12.0	1.8	10.2	1421.4	54.2	369.8
	Standard deviation	20.3	2.2	19.7	289.8	25.6	88.3
Spring 2010	Average	6.8	3.0	3.8	1460.7	52.4	301.0
	Standard deviation	4.2	4.0	1.2	273.3	23.3	34.4
Autumn 2010	Average	6.3	0.4	6.7	917.8	46.4	327.1
	Standard deviation	9.4	1.3	10.6	181.6	20.6	46.5

Year	Parameter	Mg	Ca	Na	Fe	Mn	Zn	Cu
Autumn 2009	Average	267.4	5200.1	35.3	6.8	4.4	0.9	1.1
	Standard deviation	54.5	2418.3	6.3	4.9	1.7	0.3	0.3
Spring 2010	Average	277.9	4579.8	29.2	6.1	3.5	0.6	0.9
	Standard deviation	47.5	1519.3	7.6	4.0	1.7	0.3	0.2
Autumn 2010	Average	243.1	3335.4	34.4	4.0	3.4	0.9	0.9
	Standard deviation	37.2	1547.3	9.7	2.2	4.0	0.3	0.1

HABOVŠTIAK – DANIEL (2001) indicate that in the production year an average yield of 12.0 to 15.0 $t.ha^{-1}$ dry matter is probable. With this statement we can only agree with ULV variety, since its yield was higher than 12.0 t of dry matter.$ha^{-1}yr^{-1}$ (plant spacing A: 12.46 $t.ha^{-1}.yr^{-1}$ and plant spacing B: 13.80 $t.ha^{-1}.yr^{-1}$).

Wood ash obtained from a bottom area of the boiler after burning of biomass originated from the burning of clean and chemically untreated wood from the thermal CHP

power plant in Hriňová. Content of hazardous elements in the applied wood ash (As, Cd, Cr, Hg, Pb) was lower than limit values of risk mineral elements of calcium and magnesium-calcium fertilizer under the Ministry of Agriculture Regulation from 15.12.2000, stipulating the types of fertilizers, the content of risk elements, conditions of sampling and methods for testing fertilizers, Coll. of Laws 26/2001, Supplement No. 2., content and other elements considered to be risky in the raw material for compost (Cu, Mo, Ni, Zn) was lower than the limit values of risk elements in raw materials for composting, according to STN 46 5735 "Industrial composts". Wood ash contained 11.5% calcium, 4% potassium and 1.4% magnesium.

Table 3

Measured parameters of basket willow (*Salix viminalis* L.) during four-year period (2004 – 2007).

Parameters \ Variety / Arrangement		ORM/A	ORM/B	ULV/A	ULV/B	RAPP/A	RAPP/B
Number of plants.m^{-2}		2.00	2.67	2.00	2.67	2.00	2.67
Average branch length (m)	9th year	1.45	1.95	1.67	1.87	1.42	1.47
	10th year	2.58	2.58	2.74	3.04	1.95	1.89
	11th year	3.18	3.25	3.24	3.68	2.58	2.83
	12th year	4.12	3.90	4.18	4.27	3.62	3.34
Average branch width (mm)	9th year	8.5	10.8	9.5	9.3	8.1	7.6
	10th year	10.7	13.4	11.0	12.4	10.2	9.8
	11th year	12.8	15.7	13.8	15.4	12.5	12.1
	12th year	13.7	17.6	16.6	18.2	14.0	13.2
Average weight of one branch after drying up (g)	9th year	286	350	450	420	134	85
	10th year	1050	960	1120	1090	460	385
	11th year	2002	1680	1972	1851	820	765
	12th year	2480	1940	2680	2490	1038	990
Weight of sample in dry matter (g)	9th year	2860	3500	4500	4200	1340	850
	10th year	10500	9600	11200	10900	4600	3850
	11th year	20020	16800	19720	18510	8200	7650
	12th year	24800	19400	26800	24900	10380	9900
Dry matter yield (t.ha^{-1})	9th year	6.20	8.50	5.90	7.60	2.90	5.52
	10th year	19.35	22.80	18.55	20.30	5.20	12.40
	11th year	36.20	32.10	38.50	34.40	10.15	22.65
	12th year	44.23	38.30	49.85	55.20	16.70	31.80

CONCLUSIONS

Fast growing basket willow – common osier *(Salix viminalis* L.) has been grown on experimental base in Dolná Malanta, Nitra, Slovakia since 1996. In 12 years of its cultivation, the crop has been retained in a condition suitable for energetic, but also for therapeutic purposes and creates conditions for further observation and assessment in future. By

experiment, the influence of factors on above-ground biomass production was studied: variety (ORM, RAPP, ULV), design of crop organization (method A – double rows = 0.5 m × 0.75 m or 1.25 m; method B = 0.5 m × 0.75 m) and the impact of crop years (2004 – 2007). From dried and weighted samples of plant rods following conclusions can be drawn. In the 12th year of cultivation, the height of vegetation ranged from 3.34 m (RAPP/B) to 4.27 m (ULV/B). The highest average height of vegetation was in variety ULV 4.23 m, followed by ORM 4.01 m and the lowest height was recorded in a variety RAPP 3.48 m. The average thickness of plant rods ranged from 13.2 mm RAPP/B to 18.2 mm ULV/B. Yield of the third harvest period measured in dry matter varied in significantly wide range: from 16.7 (RAPP/A) to 55.2 t.ha^{-1} (ULV/B). Based on measured and calculated data the varieties of willow can be ordered according to their suitability for the conditions of southern Slovakia as follows: 1. ULV (52.5 t.ha^{-1}); 2. ORM (41,3 t.ha^{-1}); 3. RAPP (24.3 t.ha^{-1}). In terms of planting organization, better results were achieved in planting space B (41.8 t.ha^{-1}) than in planting space A (36.9 t.ha^{-1}).

The result of the project "Efficiency of fertilization potential of wood-ash for energy plants cultivation as renewable energy resources (Ash as fertilizer)" will be the determination of an appropriate procedure in application of wood ash for the intensification of energetic plants cultivation. Since, in accordance with the Slovak Republic legislation, it is allowed to use wood ash only for the scientific purposes, we assume that the results obtained in this project will be applied in the modification of legislative framework to enable the use of wood ash for applying nutrients in energetic plants cultivation.

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