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THE POTENTIAL OF ROMANIAN AND SWEDISH WILLOW FOR SHORT ROTATION COPPICE IN THE SPECIFIC CONDITION OF BANAT PLAIN: A COMPARATIVE ANALYZE

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ABSTRACT. *Willow short rotation coppice was developed in Europe in the last decades due to increased of renewable energy importance. In order to identify and produce fast-growing willow, well adapted to a wide range of environment and also to pest and disease, research have been made. In Romania willow short rotation coppice has been developed from 2005, exclusively on agricultural, non-forest land. Swedish clone Inger was the most used clone to established willow short rotation coppice, but a few others were used especially in small experimental trails. In order to test the performance of Swedish willow clones and the ability of Romanian willow for SRC, a comparative analyze of 14 willow genotypes, seven Swedish clones ('Inger', 'Jorr', 'Olaf', 'Torra', 'Tordis', 'Torhild', 'Sven') and seven Romanian ones ('RO892', 'RO1077', 'RO1082', 'Cozia_1', 'Fragisal', 'Pesred', 'Robisal') were established in Western Romania. The differences between clones in terms of sprouting capacity and biometric observation (diameter at the base of the shoot and the maximum height of the shoot per stool) were highlighted. Clone 'Inger' and 'Sven' showed good performance in the specific soil and climatic condition analyzed, the other Swedish clones do not perform well. Good results were obtained by Romanian clones 'RO1077' and 'RO892'.*

KEY WORDS*: willow, biometric observations, short rotation coppice*

INTRODUCTION

Starting from 1970, the willow short rotation coppice (SRC) is cultivated in Sweden to produce biomass (Dimitriou & Arasson 2005) and this concept was exported to several countries especially in England and Ireland (Verwijst 2013). Over the time research have been made in order to identify and produce fast-growing willow, well adapted to pest and disease (Caslin et al. 2012). All of these clones are adapted to Sweden climatic condition but in Europe there is a wide range of environment so the use of these clones must be tested. In Romania, willow short rotation coppice has been developed from 2005, exclusively on agricultural, non-forest land. Since then, over 800 ha of willow SRC has been established (Nicolescu & Hernea 2015), half of them in Banat area (Hernea et al. 2015). Inger is the most cultivated commercial Swedish clone in Romania (Hernea et al. 2015) but a few experimental trial established with another Swedish clone like Tordis, Tora, Stina, Gudrun, Klara, Sven, Olof, (Trava 2014). The aim of this study is the comparative analyze of 14 willow genotypes, seven Romanian ones ('RO892', 'RO1077', 'RO1082', 'Cozia_1', 'Fragisal', 'Pesred', 'Robisal') and seven Swedish clones ('Inger', 'Jorr', 'Olaf', 'Torra', 'Tordis', 'Torhild', 'Sven'), in the first and second vegetation season, in order to test them for willow short rotation coppice in Western Romania.

MATERIALS AND METHODS

The research was conducted in the Didactic Station of BUASVM from Timisoara, Timis County, Romania. The area is located in the North part of the city ($45^0$78' N latitude. $21^0$22' E longitude, 90m a.s.l.). The soil is chernozem, pH=6.01, low humus (H) content (H=1.92%), medium content in nitrogen (N_t) and potassium (K) (N_t=0.101%, K=93.0 ppm), and a low content in phosphorus (P) (P=15.7 ppm). The climate is continental with south-Mediterranean influence. The mean annual temperature is 11^0C and the total annual precipitation is 600 mm based on the observation made to Timisoara Meteorological Station. The experimental trail was established in 2015 using 20 cm cuttings from National Institute for Research and Development in Forestry "Marin Drăcea" (NIRDF) ('RO892', 'RO1077', 'RO1082'), The

Fruit Growing Research and Development Unit of Vâlcea (SCDP Vâlcea) and CHPs Govora ('Cozia', 'Fragisal', 'Pesred', 'Robisal') and from a Holland Alma Kft Hungarian Nursery ('Inger', 'Jorr', 'Olof', 'Sven', 'Tora', 'Tordis', 'Torhild'). The land was prepared by ploughing and disking and a systemic herbicide was used. No chemical or organic fertilizer and no irrigation have been applied in the two experimental years. A number of 46 cutting from each genotype were manually planted in double rows. The distance within and between double rows was 0.75m respectively 1.5m and. Along the row, the distance between cuttings was 0,8m. During the establishment phase, a pre-emergent residual herbicide was applied in order to keep the crop clean and contact herbicides were over-spraying. Manual and mechanical weed control using inter-row cultivators were also used to control weeds. In 2016 (February), before the starting of the growing season, half of the plants (the second row of each genotype) was cut-back in order to highlight the sprouting capacity. The evaluation of quantitative characteristics was made by measurement of diameter (0,01mm precision) and the maximum height of every plant (1 cm precision). The plants were evaluated in July and November 2015 and also in June 2016. The statistic analyze was performed using STATISTICA 10.0 program.

RESULTS AND DISCUSSIONS

Survival rate. In practice, for a successful plantation, the survival rate has to be over 90% (Bennick et al. 2008). A good percentage of survival was obtained in July 2015 for almost every genotypes, except Romanian 'Cozia_1' and 'Fragisal' and Swedish clone 'Tora' with a survival rate less than 80 (Table 1). All the survival rate were lower in November 2015, probably because of the hot and dry summer. The highest losses have occurred on genotypes 'Cozia_1', 'Fragisal', 'Tora' and 'Thorhild'. In short rotation coppice, quantitative characteristics like diameter and height of the shoots and also the sprouting capacity (number of shoots per stool) are important. These simple measurements could suffice for biomass yield estimates through allometric relationship. Analysis of variance revealed that the effect of genotype on yield parameters is very significant in the first year of culture as well as in the second year (Table 2). The sprouting capacity is significantly enhanced by the cutback performed in February 2016 ($F=157,2200$, $p = 0.000$) (Table 3).

Table 1. The survival rate at the experimental trial establised in July and November 2015.

Inventory date	Survival rate for genotypes (%)													
	RO892	RO1077	RO1082	Cozia_1	Fragisal	Pesred	Robisal	Inger	Jorr	Olof	Tora	Tordis	Torhild	Sven
July 2015	96	98	91	74	78	93	91	98	89	93	80	96	98	98
November 2015	89	89	89	61	61	85	85	89	78	89	76	87	78	91

Table 2. The effect of genotype on the main biometric parameters in the first growing season (2015).

Analysis of Variance (2015) (genotype). Marked effects are significant at p < ,05000		
Parameter	F	p
Number of shoots per stool inventored in July 2015	7.25522	0.000000
The height (cm) of the heighest shoot per stool inventored in July 2015	44.28962	0.000000
Number of shoots per stool inventored in November 2015	7.65098	0.000000
The diameter (mm) at the bottom of the heighest shoot per stoold inventored in November 2015	45.85623	0.000000
The height (cm) of the heighest shoot per stool inventored in November 2015	50.76070	0.000000

Table 3. The effect of genotype and the cutback on the sprouting capacity and plants development (July 2016).

Analysis of Variance 1x2 (2016) 1-genotype, 2 cutbak. Marked effects are significant at p < ,05000			
Factor	Character	F	p
Genotype	The maximum height (cm) of the shoots per stool	47.11389	0.000000
	Number of shoots per stool	8.68121	0.000000
Cutback	The height (cm) of the heighest shoot per stool	9.3929	0.002297
	Number of shoots per stool	157.2200	0.000000
Genotype x Cutback	The height (cm) of the heighest shoot per stool	31.84761	0.000000
	Number of shoots per stool	21.04617	0.000000

In 2015 in the first four months of the growing season, plant growth was modest, most of the genotypes reaching a height of 40-50 cm, except Swedish clones 'Inger' and 'Sven'. Both clones reached over 90 cm height, beeing in the first class of heigh (a) and registering significant differences from the other genotypes. In terms of Romanian clones, only hybrids from NIRDF showed a high potential for this parameter with values comparable with the average growth of Swedish clones (classes b and c). The lowest growth rate was registered by 'Fragisal', 'Cozia_1', 'Robisal', 'Pesred', which registered values under 30 cm heigh (class d) (Table 4).

Table 4. Maximum height (cm) of the shoots per stool for willow clones/genotypes*.

Genotype	Mean ± SE	DT	Mean ± SE	DT
	July 2015		November 2015	
RO892	44.89 ± 3.18	cb	111.78 ± 7.65	b
RO1077	54.22 ± 3.50	b	140.73 ± 5.86	a
RO1082	44.88 ± 2.97	cb	93.64 ± 6.44	c
Cozia_1	23.38 ± 2.17	d	29.54 ± 3.19	f
Fragisal	19.58 ± 1.34	d	26.68 ± 1.67	f
Pesred	28.37 ± 2.38	dc	35.90 ± 2.99	f
Robisal	25.47 ± 1.67	d	60.64 ± 4.79	ed
Inger	94.44 ± 5.41	a	124.39 ± 5.93	ba
Jorr	36.46 ± 3.39	c	41.53 ± 3.57	fe
Olof	56.09 ± 3.79	b	79.63 ± 5.37	c
Tora	41.76 ± 2.73	c	52.54 ± 3.50	e
Tordis	54.89 ± 3.04	b	65.50 ± 4.10	d
Torhild	57.56 ± 4.50	b	77.28 ± 6.38	dc
Sven	95.44 ± 5.00	a	130.45 ± 6.21	a
All groups	49.65 ± 1.33		79.78 ± 2.14	

* Dates registered in July and November 2015. Statistical parameters (DT – Duncan Test).

At the end of the growing season, Romanian hybrids 'RO1077' (a), 'RO892' (b) reached high values of the height with a much more important increment in the second part of the growing season comparative with Swedish genotypes (Table 4). Taking advantage in the first part of the

growing season, Swedish clones 'Inger' and 'Sven' have achieved the highest value for the height (classes a and b), even if the growth in the second part of the growing season was lower, probably due to the hot and dry summer. Unsatisfactory results obtained, in the specific site condition of BUASVM Timisoara, for genotypes 'Cozia 1', 'Fragisal' and 'Pesred' (class f), even researchers made in Oltenia showed good results, comparable with Swedish genotypes 'Inger' and 'Tordis' (Botu et al. 2013). There was established a significant positive correlation between the survival rate (SR%) and the growth of the plants in the first growing season in July ($r = 0.67204^{**}$, $p = 0.008$), as well as in November 2015 ($r = 0.74121^{**}$, $p = 0.002$) (Fig.1). The same observation was made by Mosseler & Major (2015), in a study on *Salix interior* genotypes.

According to the methodology, the second row of each genotype was cutback, so in 2016, the analyze of the character "height" was made separately for harvested and unharvested plants (Table 5). The highest values for "uncut variant" were recorded for Romanian hybrids 'RO1077' (a), Swedish clone 'Sven' (b) but also 'RO892' and 'Inger' (bc). Results were partially different for cutback willow where the highest values were recorded for Romanian hybrid 'RO1077' (a), and Swedish clone 'Sven' (a) and 'Torhild' (b). The clone 'Torhild' (b) has to be notice according to very important growing capacity after cutback the shoots. For two others clones, 'Sven' and 'Robisal', the values for the mean of the stool height was higher is cutback variant than the uncut variant, after the first growing season. Very low values have been recorded for the same 'Cozia_1' and 'Fragisal', like measurements made in 2015 but also 'Jorr' (de), 'Tora' (de) and 'Tordis' (e). In 2016, the height growth followed the same tendency like the growth in 2015 for most of the clones.

It is known that one of the advantages of willow cultivation for short rotation coppice is its high sprouting capacity (Mola Yudegao 2014; Pacaldo et al. 2013). If researches have been made on Swedish commercial clones, not the same can be said about Romanian ones. In order to highlight this capacity of willow clones, observations were made in 2015 and also in 2016 after the cutback of the half the willow (Table 6). The average number of shoots per stool recorded at the end of the growing season and in June

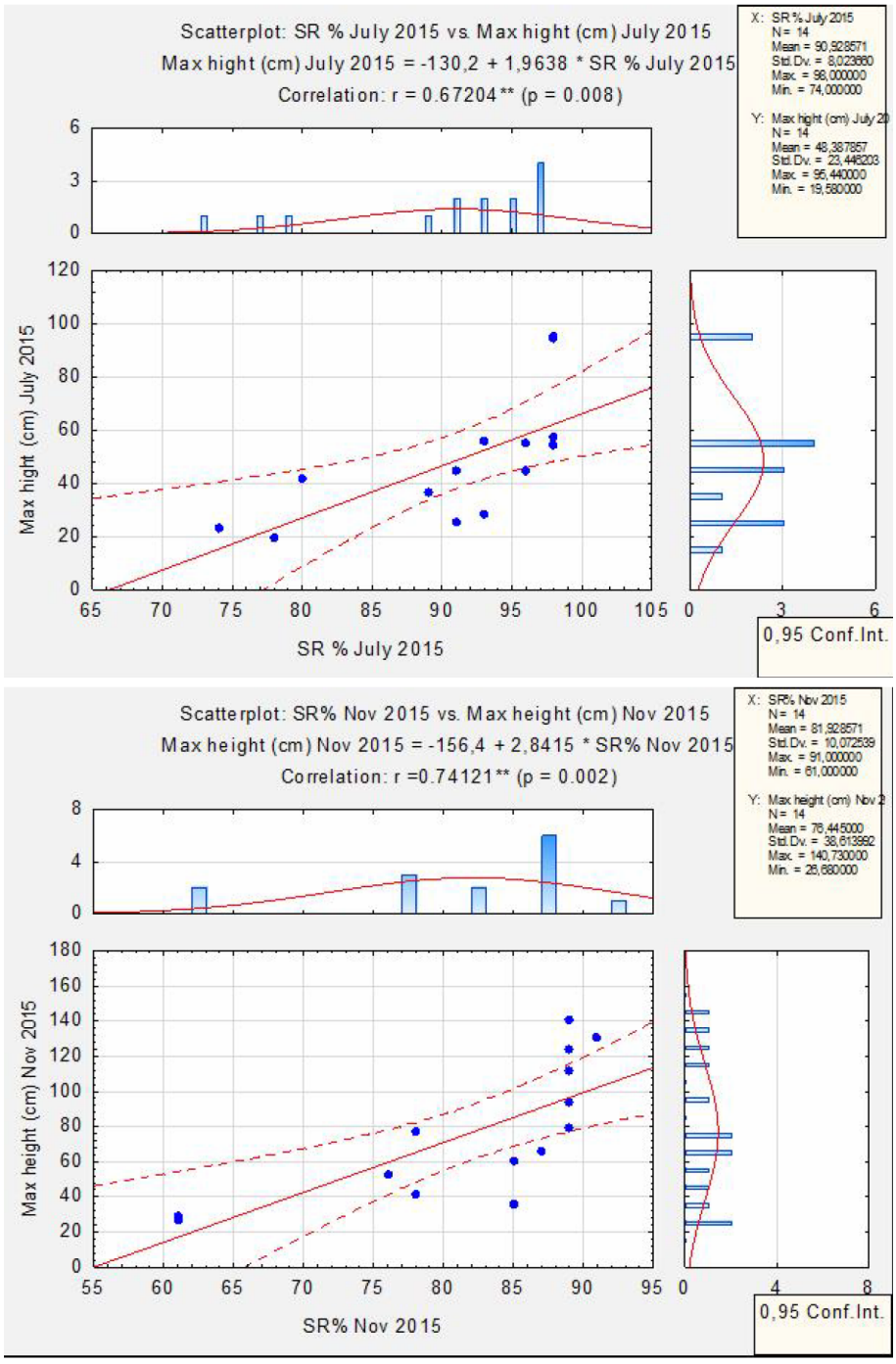

Figure 1. Relashionship between survival rate (%) and the maximum heigt of the shoot (cm). Observations were made in July and November 2015.

Table 5. Maximum height (cm) of the shoots per stool for willow clones/genotypes depending on experimental variant (uncutted/cutback)*

Genotype	Survival rate %	Mean ± SE	DT	Survival rate %	Mean ± SE	DT
		uncutted			cutback	
RO892	83	160.00 ± 5.91	bc	91	119.05 ± 10.40	b
RO1077	96	229.23 ± 3.92	a	91	158.14 ± 8.94	a
RO1082	96	133.36 ± 6.70	c	96	101.45 ± 8.58	bc
Cozia_1	52	47.50 ± 8.41	de	39	48.89 ± 5.66	de
Fragisal	70	45.31 ± 8.80	e	52	44.50 ± 5.37	de
Pesred	96	55.36 ± 5.88	de	70	58.38 ± 8.17	d
Robisal	91	66.14 ± 10.37	de	96	79.23 ± 5.16	cd
Inger	74	158.88 ± 7.26	bc	91	93.71 ± 7.60	c
Jorr	74	59.76 ± 6.76	de	83	51.37 ± 5.25	de
Olof	83	137.32 ± 8.58	cb	70	96.75 ± 10.87	bc
Tora	74	75.71 ± 13.54	de	48	54.73 ± 10.55	de
Tordis	61	73.79 ± 9.74	de	65	28.67 ± 3.03	e
Torhild	74	78.12 ± 13.08	d	78	122.22 ± 11.34	b
Sven	91	169.00 ± 10.52	b	87	170.30 ± 8.42	a
All groups		111.10 ± 4.33			93.97 ± 3.47	

* Dates registered in July 2016. Statistical parameters (DT-Duncan Test).

2016, for "uncut" variant is quite similar for most of the Romanian genotypes. An increase of shoots number per stool have been registered for Swedish clones even any cuttings were made. The sprouting capacity of analyzed clones was recorded in 2016, after the cut-back of the half of the willow. Only for clone 'Inger' have been recorded similar value of number of shoots per stool like value noticed by Castlin et al. (2015) (4-8 number of shoots per stool), for others clone (3-6 for 'Tora', 'Tordis' and 'Torhild'; 4-7 for 'Olof' and 6-10 for 'Jorr') the average number of shoots per stool registered in experimental trial from BUASVM were significantly lower.

Results showed a higher capacity of sprouting (Fig. 2) for clones 'Inger' (14) and 'Sven' (11), but also for Romanian hybrids 'RO892' (13) and 'RO1077' (12). High average values were noticed for Romanian genotypes 1077 (7.71) and Swedish clone 'Inger' (6.76). The lowest values have been noticed for Swedish clone, 'Olof' (2.13), 'Tora' (2.18) and 'Tordis' (2.27), but also for Romanian genotypes 'Fragisal' (2.08), 'Pesred' (2.38), 'Cozia_1'

Table 6. Number of shoots per stool for willow clones/genotypes*

Genotype	Mean ± SE	DT	Mean ± SE	DT	Mean ± SE	DT
	2015		2016 uncutted		2016 cutback	
RO892	1.47 ± 0.10	bc	1.58 ± 0.19	b	5.95 ± 0.74	b
RO1077	1.72 ± 0.09	b	1.50 ± 0.13	b	7.71 ± 0.56	a
RO1082	1.28 ± 0.09	bc	1.32 ± 0.17	b	2.95 ± 0.41	c
Cozia_1	1.26 ± 0.12	bc	1.33 ± 0.19	b	2.67 ± 0.47	c
Fragisal	1.56 ± 0.12	bc	1.63 ± 0.24	b	2.08 ± 0.40	c
Pesred	1.65 ± 0.12	bc	1.64 ± 0.14	b	2.38 ± 0.39	c
Robisal	1.35 ± 0.11	bc	1.14 ± 0.08	b	6.05 ± 0.78	ab
Inger	2.52 ± 0.17	a	2.76 ± 0.22	a	6.76 ± 0.70	ab
Jorr	1.16 ± 0.06	c	2.18 ± 0.43	a	3.47 ± 0.33	c
Olof	1.15 ± 0.05	c	1.58 ± 0.18	b	2.13 ± 0.18	c
Tora	1.13 ± 0.09	bc	1.41 ± 0.19	b	2.18 ± 0.33	c
Tordis	1.25 ± 0.05	bc	1.43 ± 0.17	b	2.27 ± 0.33	c
Torhild	1.20 ± 0.05	c	1.76 ± 0.22	b	2.50 ± 0.35	c
Sven	1.38 ± 0.10	bc	2.43 ± 0.46	a	5.15 ± 0.54	b
All groups	1.43 ± 0.03		1.69 ± 0.07		4.20 ± 0.19	

*Data registered in November 2015 and July 2016. Statistical parameters (DT-Duncan Test)

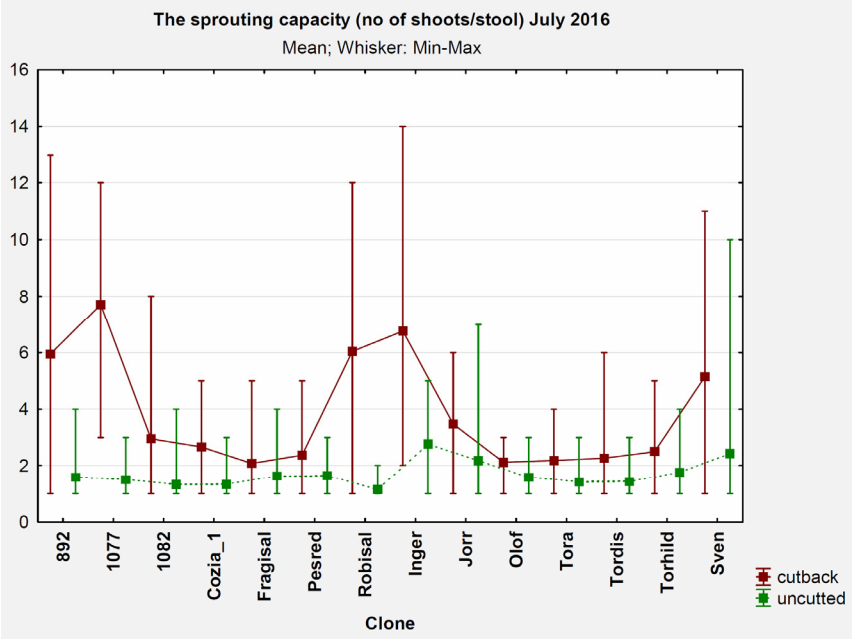

Figure 2. Sprouting capacity of willow clones registered in July 2016. Number of shoots per stool in two experimental variants, uncutted and cutback.

(2.67) and 'RO1082' (2.95). An important element for yield estimation, base in destructive or non-destructive methods is the diameter. The mean values of the diameter at the base of the stool at the end of the first growing season are presented in Table 7. The largest diameter was recorded for Romanian hybrid 'RO1077' (14.00 mm) (a) and Sweedish clone 'Sven' (10,76 mm) (b), which recorded a significant difference, in comparison with 'RO1077'. In the same category (b) of values for stem diameter are hybrid 'RO892' (9,71 mm) and clone 'Inger' (9,80 mm). Lowest diameter values were observed for genotypes 'Cozia_1' and 'Fragisal', which are part of the last group, concerning this parameter.

Table 7. Diameter (mm) at the bottom of the highest shoot per stool of willow clones/genotypes measured in November 2015*

Genotype	Mean ± SE	DT	Min	Max
RO892	9.71 ± 0.56	b	4.14	18.86
RO1077	14.00 ± 0.67	a	5.93	20.45
RO1082	8.19 ± 0.42	c	3.18	14.17
Cozia_1	4.58 ± 0.22	e	3.21	7.47
Fragisal	4.68 ± 0.19	e	2.80	6.68
Pesred	4.86 ± 0.20	e	2.71	8.27
Robisal	7.07 ± 0.42	cd	2.92	13.06
Inger	9.80 ± 0.39	b	5.12	16.41
Jorr	5.68 ± 0.25	de	3.73	9.22
Olof	6.57 ± 0.26	d	3.61	9.89
Tora	5.93 ± 0.25	de	2.89	8.79
Tordis	6.67 ± 0.21	d	3.68	9.67
Torhild	6.84 ± 0.38	d	3.53	12.60
Sven	10.76 ± 0.48	d	5.56	20.51
All groups	7.73 ± 0.16		2.71	20.51

*Statistical parameters (DT - Duncan Test)

CONCLUSIONS

The result of this study highlight the differences between fourteen willow clones in terms of sprouting capacity and biometric observation. The num-

ber of shoots per stool ranged between 1 and 14 and the average height of shoots ranged between 26.69 and 140.73cm. Not all the Swedish clones showed good performance in soil and climatic condition on BUASVM Timisoara. They showed better results that Romanian clones delivered by SCDP Vâlcea but not superior to Romanian clones delivered by NIRDF. Best results were showed by Romanian clones 'RO1077' and 'RO892' and Swedish clones 'Inger' and 'Sven'.

REFERENCES

Bennick, J., Holway, A., Juers, E., Surprenant, R. (2008): Willow Biomass: An assessment of the ecological and economic feasibility of growing willow biomass for Colgate University. ENST Spring 2008, pp. 35.

Botu, I., Botu, M., Preda, S., Achim, G., Lazăr, A., Alecu, A. (2013): Comparative evaluation of romanian and introduced salix cultivars for short rotation coppice. South-western Journal of Horticulture, Biology and Environment 4(1): 35-42.

Caslin, B., Finnan, J., McCracken, A. (2012): Willow varietal identification guide. Teagasc & AFBI. 64p.

Dimitriou, I., Aronsson, P. (2005): Willows for energy and phytoremediation in Sweden, UNASYLVA-FAO (56):47-50.

Hernea, C., Hollerbach, W., Trava, D., Corneanu, M. (2015): The behaviour for SRC willow inger in experimental trial Ghilad, Romania. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca Horticulture 72(2):376-380.

Mola-Yudego, B., Dimitriou, I., Gonzalez-Garcia, S., Gritten, D., Aronsson, P. (2014): A conceptual framework for the introduction of energy crops. Renewable Energy 72: 29-38.

Mosseler, A., Major, J.E. (2015): Biomass and root stem production of a colony-forming willow (*Salix interior*) on highly disturbed, low fertility sites. Biomass and Bioenergy 74: 202-212.

Nicolescu, V.N., Hernea, C. (2015): Romania. In Evolution and perspectives of coppice forests in European countries and South Africa. (eds. Nicolescu N.V., Pyttel P., Bartlett Debbie). Ed. Aldus, Brasov.

Pacaldo, R.S., Volk, T.A., Briggs, R.D. (2013): No significant differences in soil organic carbon contents along a chronosequence of shrub willow biomass crop fields. Biomass Bioenergy 58: 136-142.

Trava, I.D. (2014): Cercetări comparative privind productia de biomasa la specii si clone de salcie repede crescatoare, in vederea creşterii eficienţei energetice., PhD Thesis, BUASVM Timişoara, Romania.

Verwijst, T., Lundkvist, A., Edelfeldt, S., Albertsson, J. (2013): Development of sustainable willow short rotation forestry in northern Europe. pp: 480-502. In: Matovic, M.D. (ed.), Biomass Now – Sustainable Growth and Use.