RESEARCHES CONCERNING THE POSSIBILITY OF CULTIVATING ENERGETIC WILLOW ON DEPOSIT OF ASH FROM THERMAL POWER STATIONS

Marin Soare[1], **Paula Iancu**[1*]**, Ovidiu Panita**[1]**, Rodica Soare**[1]**, Elena Bonciu**[1]

[1] University of Craiova, Faculty of Agronomy, **Romania**
[*]corresponding author: paula.iancu76@gmail.com

ABSTRACT

Energetic crops are increasingly used as renewable sources of energy as well as for their ability to fix and accumulate carbon in the soil. Willow culture for biomass promotes rural development and environmental protection, especially if it is established in areas less favorable for agricultural crops.

Researches from this work has been carried out in a wide range of genotypes of *Salix* sp. cultivated on a deposit of ash resulting from coal burning to Isalnita Power Station, near Craiova, Romania, over a period of two years of vegetation. Determinations were made regarding plants growth and development such as stem height, no. of shoots/plant and stem diameter at the base, as well as on the development of the root system, determining the number and weight of roots.

The results were statistically interpreted by analysis of variance method, LSD 5%, and the principal components analysis. Hydric stress is one of the main factors of limiting plant growth on this type of artificial substrate and the experimented willow genotypes have reacted differently. It emphasizes with good results in terms of the quantity of biomass RO 1077, Fragisal, Robisal and Torhild genotypes.

An interesting phenomenon as concern root morphology, on the ashes from Isalnita is that there were identified many side branches especially in the 0-20 cm, with a thin appearance.

INTRODUCTION

The resulting ash by burning coal in thermal power stations is the most important industrial waste. Re-processing of heaps of ash consists in a complex of technological and biological measures aimed to curb the phenomenon of deflation and turn in final storage area, which is a strong source of environmental pollution in a new natural space, able to support the development of the plant. On the ash dumps can be cultivated several species of plants, especially those with energy potential, such as willow.

Energy willow is one of the plants cultivated for superior calorific properties, therefore pellets made of this burning better than wood.

Apart from the exploitation of biomass for energy, this crop it is appropriate for forestry wind brakes, due to specific properties: minimal requirements regarding soil quality, rapid growth, forming dense bushes, etc.

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Willow can be grown on various soil types, but soil types which ensuring a good supply of water are suitable. Light soil types without irrigation will result in unstable yield **[1]**.
Woody biomass crops, such as willow, act as substitutes to politically, socially and environmentally insecure fossil fuels. Short rotation woody crops, such as willow shrubs, could sequester 4.5-8 tons of carbon per hectare per year **[2]**. Because as trees reach maturity their potential to sequester decreases (in conjunction with a decrease in their growth rate), willow biomass is a particularly good method to sequester carbon because of its short growing time; effectively making the willow shrubs always young, and thus at their optimal sequestration capacity **[3]**. Willow is very much a long-term investment. When growing willow, most of the costs are paid up front, as the site must be prepared and the willow must be purchased and planted. The benefits are, however, collected for over twenty years with lower costs during this period that include the cost of harvests and upkeep of the plants **[4]**. The material obtained from willow can be fur er processed into various forms of solid fuels. In this case, the mechanical properties are important, i.e. volume weight and mechanical solidity. These parameters depend on used material, its structure, water content and compacting pressure **[5]**. In Romania, willow short rotation coppice has been developed from 2005, exclusively on agricultural, non-forest land. Inger is the most cultivated commercial Swedish clone in Romania **[6]** but a few experimental trials established with another Swedish and Romanian clone. In the last years, a lot of information is obtained about harvesting yields, cost of harvesting, and soil types preferred by willow. From this point of view, in the present study was tried the growing of the willow on the ashes deposit (ash dump) and draw some conclusions concerning the suitability of willow for cultivating on this type of substrate.One of the main benefits of cultivation of perennial energy crops on ash is represented by the environmental effect of preventing wind erosion/deflation.
The aim of this study is the comparative analyze of fourteen willow genotypes, seven Romanian one and seven Swedish clones, in the first and second vegetation season, in order to test them for willow short rotation coppice in this condition.

MATERIALS AND METHODS

The research was conducted on a deposit of ash resulting from coal burning to Isalnita Station, near Craiova, Romania, over a period of two years. The area is located in the West part of the city ($44^0$24’ N latitude. $23^0$41’ E longitude). The climate is continental, the mean annual temperature is 11^0C and the annual precipitation sum is between 387-680 mm, with 188-520 mm in the growing period.
The experimental trail was established in April 2015, using 20 cm cuttings of seven Romanian genotypes ('RO892', 'RO1077', 'RO1082', 'Cozia 1', 'Fragisal', 'Pesred', 'Robisal') and seven Swedish clones ('Inger', 'Jorr', 'Olof', 'Torra', 'Tordis', 'Torhild', 'Sven') and was designed according to randomized complete block split-block with three replications, applying conventional crop technology of energy willow.
The evaluation of quantitative characteristics was made by measurement of number of sprouts, diameter (0,01mm precision) and the maximum height of every plant (1cm precision).
Aboveground material from each sample, excluding any remaining leaves, was cut into 25cm lengths, weighed, then oven dried at 80°C for 96 h, and reweighed immediately. The resulting dry mass (DM) data are regarded as the biomass yield. The genotype was the only analyzed factor, data collected were statistically analyzed with ANOVA using the Fisher’s technique. The least significant difference (LSD) test at 0.05 was used to compare averages

RESULTS AND DISSCUTIONS

The area with termocentrale ash was no longer in use. The use of these areas for agriculture was not an attractive alternative, whereas forestry offers an interesting way to cultivate and fixing them. Succesfull willow experiment under the conditions prevailing on termocentrale ash, would require the selection and development of new willow clones more adapted to these condition. It has been observed that willow clones tested, do not adapted well enough to local conditions, especially as far as resistence to drought is concerned. Climatic conditions from Isalnita are relatively favorable only in the first half of vegetation period of the year (Fig. 1). After that period, the temperature rise and drought occurs, which cumulates with poor water retention capacity by the ash, thus makes plants to be exposed to hydric and heat stress, affecting plants growth and development.

Regarding the climatic conditions during the growing season, there were recorded temperature oscillations, very dry periods or excess rainfall in a short time. In July and August rainfall was low and the temperatures were very high, which strongly influenced the growth of plants.

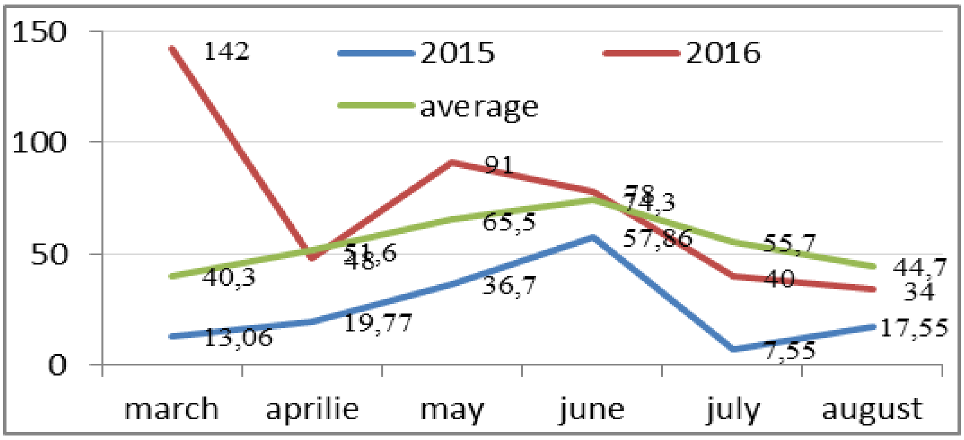

Fig.1. Variation of monthly average rainfall (mm) during March -August in the experimentation area

Survival rate is an essential element for the willow crop success and it is influenced by the cuttings used on the planting, but also it is influenced by the climatic conditions immediately after planting.

On this experiment in 2015 the survival rate was different depending of genotype, with values between 72.71% and 96.80% in the first part of the season. Considering the harsh climatic conditions from summer months, along with high temperature and lack of rainfall, the plants suffered, did not grow and some of emerged plants died, because of the soil drought installation. From table 1 it can be seen that the survival rate diminished drastic, with low values, all genotypes being affected by adverse environmental conditions. The trees that did not survive were replaced with new cuttings in the spring next year.

Table 1

Survival rate for genotypes (%)

Genotyp / Date	RO892	RO1077	RO1082	Cozia	Fragisal	Pesred	Robisal	Inger	Tordis	Olof	Sven	Tora	Jorr	Torhild	X	Stdev	s%
May	95.47	95.24	94.21	88.51	87.28	72.71	93.92	94.1	91.57	96.80	89.77	93,52	95.85	89.72	91.33	6.12	12.20
Nov.	59.98	55.41	44.21	58.30	58.91	64.34	58.80	59.28	59.44	59.35	59,78	60.31	58.50	58.50	58.50	3.22	17.42

This situation is due the high temperature from July and August and because of the fact that the ash is getting warmer during the day and the plants are under thermic stress from two ways: from the sun and from the soil. That makes the temperature inside the soil to reach almost 40^0-50^0C and because of that leafs and almost immediately dried.
In this condition the survival rate were substantially lower than other reported experiments, indicating that high mortality rates can be a problem **[7]**. Height growth was determined by measuring the length of main stem from the base to the lower edge of the apical leaf. The principal properties of the clones tested are set out in table 2. As concern plants height it can say that in the first months of the growing season, it was good, most of the genotypes reaching a height over 100 cm. The best result obtained Fragisal and RO 1077 genotypes with a value of 143.2cm, respectively 142.8 cm. These recorded significant differences in relation to the last nine genotypes classified, being followed by Robisal, Cozia and Torhild, identifying a statistical differentiation among all genotypes. Lower values presented Olof (59.1 cm) and Inger (65 cm). In a similar experiment have been reported an average length of annual growth ranged from 2.78 m (Fragisal) to 3.38 m (Inger) and the sum of average annual growths per plant ranged from 37.3 m (Tordis) to 59.8 m (Inger), but on another type of soil and a different rainfall regime **[8].**

Table 2

Plant height values (cm) of the studied genotypes (2015-2016)

No.	Clone	Average (x)	St.dev	s%
1	Cozia	136.7^{ab}	38.3	28.02
2	Fragisal	143.2^{a}	31.8	22.21
3	Tordis	78.2^{efg}	16.8	21.48
4	Sven	78.1^{efg}	6.9	8.83
5	Robisal	133.4^{abc}	31.6	23.69
6	RO 1077	142.8^{a}	37.2	26.05
7	RO 892	$90d^{ef}$	5	5.56
8	Pesred	107^{cd}	17	15.89
9	Inger	$65f^{g}$	5	7.69
10	Olof	59.1^{g}	4.1	6.94
11	RO 1082	107.8^{cd}	17.2	15.96
12	Jorr	98.1^{de}	16.9	17.23
13	Torhild	129.1^{abc}	30.9	23.93
14	Tora	110.2^{bcd}	24.8	22.50
LSD 5% = 27.88 cm				

Sprouting capacity is a parameter with genetic determinism, but it is also influenced by pedoclimatic conditions **[9]**. No significant differences were observed between the experimented clones in the number of shoots during the first/second growing season. The lowest number was recorded in Tordis and RO 892 clones (4.6). The highest number was found in Fragisal clone (12). A good sprouting capacity has been noticed also for Sven (6.7). The sprouting capacity of willow increases after multiple harvests [6]. The number of shoots developing per cutting during the first/second growing season is a detail of particular importance under the conditions prevailing in the southern area of Romania. It is considered important for culture success over summer to have a smaller number of shoots/cuts so that each one is stronger to withstand the heat. High growth rate of individual clones, as well as of particular stools, increases competition between stools and causes stools to die. If stool mortality is high, there is a risk of biomass production to decrease, over a long term **[10]**.

Diameter at the base of the shoot and shoot height are positively correlated and depends on soil and climatic conditions, but also have a genetic determinism. Good results for the diameter at the base of the shoot were noticed for Fragisal (8.13 mm), RO 1077 (8.1 mm), Robisal (7.57 mm), Torhild (6.83 mm). The other genotypes of willow presented lower values.

Registered values for the morphological characters such as plants height, number of stems and diameter at the base of shoot are similar with those reported for the Western Romania **[9].** Also, **[8]** sustain that average annual growth is dependent on the number of shoots.

Table 3

Variability of number of shoots/stem and diameter (2015-2016)

Crt. no	Clone	No. of shoots/stem			Base diameter (mm)		
		Average	St.dev	s%	Average	St.dev	s%
1	Cozia	$6,3^{bc}$	1,2	19,05	$7,6^{ab}$	2,6	34,21
2	Fragisal	12^{a}	1,5	12,50	$8,13^{a}$	2,63	32,35
3	Tordis	$4,6^{d}$	0,1	2,17	$6,53^{abc}$	0,67	10,26
4	Sven	$6,7^{b}$	0,7	10,45	$5,33^{bcd}$	0,53	9,94
5	Robisal	$5,9^{bcd}$	1,1	18,64	$7,57^{ab}$	1,43	18,89
6	RO 1077	$6,3^{bc}$	0,8	12,70	$8,1^{a}$	3,1	38,27
7	RO 892	$4,6^{d}$	0,4	8,70	$4,2^{d}$	0,2	4,76
8	Pesred	$5,3^{bcd}$	0,3	5,66	$4,83^{cd}$	0,17	3,52
9	Inger	$5,5^{bcd}$	0,5	9,09	$5,87^{bcd}$	0,37	6,30
10	Olof	$6,5^{bc}$	1	15,38	$4,38^{d}$	0,38	8,68
11	Ro 1082	$5,3^{bcd}$	0,3	5,66	$5,47^{bcd}$	0,47	8,59
12	Jorr	$5,1^{cd}$	1,1	21,57	$4,3^{d}$	0,3	6,98
13	Torhild	$5,7^{bcd}$	0,7	12,28	$6,83^{abc}$	0,33	4,83
14	Tora	$5,6^{bcd}$	0,6	10,71	$5,83^{bcd}$	0,83	14,24
LSD 5%=1,44 ram/pl.					LSD 5%=2,15 cm		

Salix has an extensive root system that makes it able to grow on marginal and heavy soils. A plant's root system is usually comprised of both coarse and fine roots, each having a specific ecological function. The fine root system has strong influence over the surface area and, in some cases, may exceed aboveground biomass production **[11]**. Consequently, it is important to consider fine roots characteristics in phytoremediation strategies of polluted soils.

According to other results, a significant decrease in fine root biomass of willow was observed when the highest irrigation dose was applied. These authors suggest that the supply in water and nutrient is sufficient to the development of the willows which react by diminishing the amount of roots proportionally to the above ground parts. Since roots are responsible for water and nutrient uptake, the filtering capacity and thus the efficiency of the entire system rely on root system development and functioning. About 92% of fine roots length was found in the top 20 cm of soil **[12]**.

Tested clones presented values of number of roots/plant between 6 (Tordis, Inger) and 10.3 (RO 1077) (Tab.4).

Table 4

Variability of the number f root/plant and root length (2015-2016)

Crt. no.	Clone	No. of root/plant			Root length (cm)		
		Average	St.dev	s%	Average	St.dev	s%
1	Cozia	10^{ab}	3	30.00	25^{a}	5	20.00
2	Fragisal	12^{a}	3.5	29.17	27.2^{a}	5.7	20.96
3	Tordis	6^{d}	0.8	13.33	16.1^{bc}	0.9	5.59
4	Sven	9^{bc}	0.8	8.89	14.5^{c}	0.3	2.07
5	Robisal	9.3^{abc}	2.7	29.03	20.1^{b}	1.9	9.45
6	RO 1077	10.3^{ab}	2.3	22.33	25.1^{a}	2.9	11.55
7	RO 892	9^{bc}	2	22.22	16.5^{bc}	1.5	9.09
8	Pesred	7^{cd}	0.5	7.14	17.1^{bc}	0.9	5.26
9	Inger	6^{d}	0.5	8.33	14.3^{c}	1.2	8.39
10	Olof	7.1^{cd}	0.9	12.68	17.5^{bc}	2.5	14.29
11	Ro 1082	7.2^{cd}	0.8	11.11	17.8^{bc}	1.2	6.74
12	Jorr	6.5^{cd}	0.5	7.69	16.5^{bc}	0.5	3.03
13	Torhild	8.2^{bcd}	2.2	26.83	20.1^{b}	3.1	15.42
14	Tora	7.7^{bcd}	0.7	9.09	18.4^{bc}	2.4	13.04
	LSD 5% = 2.96 root/plant				LSD 5% = 4.55 cm		

Root system is aggressive and can cause problems with drains. *Salix* gives good results on soil with groundwater at normal depth. Tested clones of *Salix* presented o root length between 14.3cm (Inger) and 25.1 cm (RO 1077).

Table 5

Variability of root and stem weight (2015-2016)

Crt. no.	Clone	Root weight (g)			Stem weight (g)		
		Average	St.dev	s%	Average	St.dev	s%
1	Cozia	41.0^{ab}	9.0	21.95	64.2^{a}	11.2	17.45
2	Fragisal	35.3^{bc}	3.8	10.76	67.3^{a}	5.8	8.62
3	Tordis	12.7^{g}	4.3	33.86	13.4^{e}	1.4	10.45
4	Sven	11.9^{g}	2.9	24.37	12.7^{e}	2.1	16.54
5	Robisal	35.8^{bc}	6.2	17.32	57.9^{ab}	5.9	10.19
6	RO 1077	46.5^{a}	8.5	18.28	66.8^{a}	11.2	16.77
7	RO 892	17.1^{fg}	0.9	5.26	13.5^{e}	4.5	33.33
8	Pesred	29.3^{cde}	8.7	29.69	16.4^{e}	1.6	9.76
9	Inger	21.2^{ef}	1.3	6.13	22.2^{cde}	3.3	14.86
10	Olof	20.2^{fg}	2.2	10.89	30.8^{c}	4.2	13.64
11	Ro 1082	31.3^{cd}	1.7	5.43	20^{de}	6.0	30.00
12	Jorr	23.1^{def}	3.9	16.88	15.6^{e}	1.4	8.97
13	Torhild	35.6^{bc}	3.6	10.11	48.2^{b}	4.2	8.71
14	Tora	32.1^{c}	2.1	6.54	27.6^{cd}	0.4	1.45
		LSD 5% = 8.47 g			LSD 5% = 9.72 g		

Root weight is in correlation with the number of the roots and their length. So, for this issue values varied from 12.7g (Tordis) to 46.5g (RO 1077). Regarding the morphology and root development on the ash of Isalnita, it was found that several lateral branches were identified, especially in the range of 0-20 cm, with a thin appearance, in most of the genotypes studied. This seems to help plants explore a larger volume of soil and capitalize on water reserves.

Plants in this genus are notably good atmospheric pollution tolerance and high wind tolerance. Stem biomass production was measured by stripping off the leaves and cutting all the shoots at the base. The dry matter content of each clone was determined in the laboratory by drying a separate fresh sample from each at 80°C for 96 h. Dry matter content in the willow clones was in the range of 12.7g to 67.3g. The highest values recorded Romanian clones: Fragisal (67.3g), RO1077 (66.8), Cozia (64.2g) and Robisal (57.9g). Among Swedish clones, Torhild registered a higher value (48.2g). Lower mean values were obtained by clones Sven (12.7g), RO892 (13.5g), Tordis (13.4g) and Jorr (15.6g).

According to the obtained results, the fast growing *Salix viminalis* clones are recommended to be selected as drought tolerant and relatively productive in termocentrale ash conditions from Isalnita. The behavior of Fragisal clone was different from the other tested clones. After first and second year of vegetation this clone insures sufficient root growth, plants height, number of shoots and dry matter content. Even if the growing season were warmer than usually and ash in summer months is more heated, the clones Fragisal and RO1077 behave quite well and can be used in future breeding program. The other tested clones differed considerably in their behavior under the conditions on these artificial substrate. However, the different growth due to climatic or clone specific factors makes it necessary to continue selection for further trials.

The obtained results suggest that it would be possible to improve some morphological characters of fast growing willow in the Southern part of Romania, but the essential problem are if is possible to find out the satisfactory ratio between summer heat tolerance and biomass production, as well as roots development. It is possible to select the best clones in terms of biomass production and summer heat tolerance and after that attempt to hybridization to obtain the optimal clone for the conditions prevailing in this region.

CONCLUSION

Re-processing the heaps of ash has the main aim to curb the phenomenon of wind deflation and to turn a hillock surface, from a strong source of pollution of the environment, in a new natural space.

The use of these areas for agriculture was not an attractive alternative, whereas forestry offers an interesting way to cultivate and fix them. Successfully willow experiment under the conditions prevailing on thermoelectric ash, would require the selection and development of new willow clones.

The result of this study highlights the differences between the fourteen willow clones in terms of sprouting capacity and the other biometric observation.

It has been observed that willow clones tested do not adapted well enough to local conditions, especially as far as resistance to drought is concerned. Climatic conditions from Isalnita are favorable only in the first half of vegetation period for growing of willow clones.

Registered values for the morphological characters such as plants height, number of stems and diameter at the base of shoot, roots length and roots weight were influenced of climatic condition

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According to the obtained results, the clones of *Salix* with faster growing are recommend to be selected as drought tolerant and relatively productive in the conditions from Isalnita with thermoelectric ash or using irrigation for increasing survival rate.

Best results were registered by Romanian clones 'RO1077', 'Fragisal' and 'Robisal' and Swedish clone 'Torhild'.

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