основания и тщательного анализа не дает существенного повышения посевных качеств семян и увеличения продуктивности культурных растений.

Природой изначально созданы совершенные способы сохранения своего потомства – посевной материал хорошо защищен от внешних воздействий. Реакция генотипа на предпосевную обработку в зависимости от уровня воздействия может быть разнообразной. В критических условиях семенной материал может погибнуть. В отдельных случаях могут произойти изменения генетической наследственности и создание новых разновидностей растений. Слабые воздействия приводят к изменению работы систем жизнеобеспечения семян и, в зависимости от направленности внешних воздействий и внутреннего состояния семян, привести к повышению или снижению жизненного потенциала прорастающих растений. Подобное взаимодействие определяется большим количеством факторов и на данном уровне развития науки его практически невозможно спрогнозировать. Нельзя с уверенностью утверждать, что какое-либо воздействие приводит к повышению качества посевного материала и дает гарантированное увеличение урожайности. Снижение продуктивности культурных растений от предпосевной обработки также вполне возможно.

С практической точки зрения необходимо точно понимать, когда и при каких условиях от предпосевной обработки можно получить увеличение урожайности, какие общие закономерности предопределяют реакцию семени на внешние воздействия. И только на основании этого создавать наиболее эффективные приемы предпосевной обработки семян.

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BENEFITS OF ECONOMIC ENTITIES THROUGH THE CO-COMBUSTION OF VARIOUS CLONES FROM THE SALIX SP. GENUS AND A MIXTURE OF DIFFERENT LIGNITE SAMPLES

ПРЕИМУЩЕСТВА ХОЗЯЙСТВЕННЫХ СУБЪЕКТОВ, ПОЛУЧАЕМЫЕ ПУТЕМ СОВМЕСТНОГО СЖИГАНИЯ КЛОНОВ ГЕНА СЕМЕЙСТВА ИВОВЫХ И СМЕСИ РАЗЛИЧНЫХ ОБРАЗЦОВ БУРОГО УГЛЯ

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Power generation depends to a great extent on the use of fossil fuels (lignite) in the Republic of Serbia. During the previous years, inadequate decisions on the development of energy and the operation of coal mines and thermal power plants led to a significant reduction in the power generation in coal-fired thermal power plants, and thus to the need to import part of the electricity. On its green road "Go Green Road" that leads to decarburization, the Republic of Serbia intends to significantly increase the use of renewable energy resources, which would compensate for the shortfall in the base portion of the daily load diagram, which threatens to be the greatest possible in the future. Due to economic reasons, the introduction of innovations is only acceptable to energy producers if it does not deviate significantly from mainstream technology, that is, if it is not necessary to invest too much in the reconstruction of already existing energy production facilities. The objective of this paper is to present the biomass energy potential of various willow clones that would be combusted, according to different percentage ratios, in a mixture of different coal samples taken from the Mining Basin Kolubara in the Public Enterprise "Electric Power Industry of Serbia". White willow clone NS 73/6 (*Salix alba*) had the highest energy potential compared with other tested willow clones. From an economical point of view, it is more reasonable to select 5 % of the *Salix alba* NS 73/6 clone biomass, in the co-combustion process with lignite.

The paper is based on the principles of the circular economy, which would connect science and the economy by implementing scientific and research findings into the economy, all aimed at protecting and preserving the environment. By applying "green" technologies to the economy, the issue of protecting the environment can be solved through simultaneous revenue generation for economic entities.

В Республике Сербия выработка энергии зависит в значительной степени от использования ископаемого топлива (бурого угля). В течение предыдущих лет, необдуманные решения по развитию энергетики, работе угольных шахт и теплоэлектростанций привели к значительному снижению выработки электроэнергии на угольных теплоэлектростанциях. Таким образом, появилась потребность в импорте части электроэнергии. Согласно проекту "Go Green Road", который нацелен на обезуглероживание, Республика Сербия намерена значительно увеличить использование источников возобновляемой энергии, которые могут компенсировать недобор части суточной нагрузки, что может стать возможным в будущем. По экономическим причинам внедрение инноваций приемлемо для производителей энергии только в том случае, если они не сильно отклоняются от основных технологий, то есть, если не нужно слишком много вкладывать в реконструкцию уже существующих объектов по производству энергии. Цель данной статьи представить энергетический потенциал биомассы различных клонов ивовых для сгорания, согласно процентному соотношению, в смеси различных образцов угля взятых из шахт бассейна Колубара государственного предприятия "Электроэнергетика Сербии". Клон белой ивы NS 73/6 (*Salix alba*) показал самый высокий энергетический потенциал по сравнению с другими тестируемыми клонами ивы. С экономической точки зрения, более резонно выбрать 5 % биомассы клона *Salix alba* NS 73/6 при процессе сжигания с бурым углем.

Данная работа основана на принципах круговой экономики, которая объединяет науку и экономику путем внедрения научно-исследовательских разработок в хозяйстве, все это нацелено на защиту и сохранение окружающей среды. Применяя "зеленые" технологии в хозяйстве, вопрос защиты окружающей среды можно решить одновременно с приобретением выгоды для хозяйственных субъектов.

Keywords: Biomass, energy potential, plants, willows, soil, sustainable development.

Ключевые слова: биомасса, энергетический потенциал, растения, ивы, почва, устойчивое развитие.

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Introduction. The Public Enterprise "Electric Power Industry of Serbia", with the support of the Government of the Republic of Serbia, has embarked on the path of decarburization, the «Go green road», and the use of biomass that would be used in co-combustion processes with lignite would benefit both PE EPS and environmental protection and preservation. The energy community treats biomass as carbon neutral, so if biomass and lignite were co-combusted to obtain energy, the amount of calculated CO_2 would be reduced, i.e. less payment of carbon taxes which will be present in the future because the co-combustion of biomass and coal contributes to the reduction of greenhouse gases.

Willows are characterized by a large number of species of various life forms, and usually, it is a tree, and they can be extremely tall up to 15 meters and up to 1 meter in diameter, although they can also look like a bush or a plant on the ground [1]. They grow mainly on flood plains, in river valleys, generally along rivers, or on marshy land.

The multiple benefits of reclamation would be achieved if energy plantings were created in this region using, at the same time, the given area would continue to "earn" through the production of biomass that would be used for power generation. These fast-growing woody plants, which are managed according to the principle of short treatment, have several characteristics suitable for the phytoremediation process, and among the most important are as follows: a strongly developed and branched root system, high biomass productivity, high intensity of transpiration, as well as genetic variability. These plantings are established from genetically improved clonal material, with a planting density of ~15000 plants/ha.

Biomass obtained from willows as a short rotation coppice (SRC) has an enviable energy potential because the heating value of willows can even reach 19 MJ/kg. Biomass obtained from willows, compared to coal, has almost no sulphur, contains lower amounts of ash and trace metals, and depending on the combustion regime and equipment, can result in lower NO_x emissions. Rodzkin et al. (2016) point out that clones of *Salix alba* and *Salix dasyclados* species, as well as *Salix aurita* and *Salix dasyclados* hybrids, are good candidates for biomass production on degraded lands [2].

Material and method of work. It is necessary to apply the appropriate scientific and research methodology to implement the planned research and fulfil the set goals.

In this paper, 4 willow genotypes were investigated: one clone of "basket willow" - *Salix viminalis* and three clones (clone B-44, clone 347, and clone NS 73/6) of white willow – *Salix alba.* The plant material of the clones used comes from the nursery in the nursery-garden of War Island in Kać, which belongs to PC[*] "Vojvodina Forests", ŠG[**] "Novi Sad", ŠU[***] "Kać".

All the cuttings used for the research were approximately the same thickness and length. In 2019, a total of 1440 cuttings, 360 cuttings per clone, were planted in the bed of the Faculty of Forestry of the University of Belgrade.

After 3 years of cultivation, the willows were cut from the bed of the Faculty of Forestry of the University of Belgrade and transported to a warehouse where they were dried naturally for 2 months. After that, they are crushed and then ground in coal mills in the accredited laboratory for coal analysis in the MB Kolubara, Processing Plant, PE EPS.

The heating values of the mixture of 3 lignite samples with 4 willow clones were determined, in different proportions: 5%, 10%, 15% and 20% of the biomass. The first and second lignite samples were taken from two localities in the eastern part of the MB Kolubara and represent mixed samples from Field B/C and Field E. The third coal sample was taken from the western part of the Kolubara basin, at the Crushing Plant-Kalenić loading point, and represents mixed coal from Tamnava West Field and Field G. All three samples were blended into one representative.

The obtained data were processed using statistical methods, namely, numerical data were obtained by measuring the calorific value of three samples of coal and the biomass of four genotypes (clones), as well as by calculating the differences between the heating value of coal and the mixture of coal with the biomass of four genotypes (clones) of willow and were processed with descriptive and univariate statistical methods.

Descriptive statistics included the determination of the following parameters: sample size (N), mean value ($\bar{X}$), minimum value (MIN), maximum value (MAX), standard deviation (±SD) and coefficient of variation (CV, %). Using the analysis of variance (ANOVA), as well as the post-hoc Fisher test of at least significant difference (LSD), differences between the caloric values of the examined coal samples and the biomass of the willow genotypes were tested. Analyses were preceded by data normality testing.

Statistical analyses were performed in the computer program Statgraphics Centurion v. XVI.I. (2009; Statpoint Technologies, Inc., Warrenton, VA).

The analyses were made in the laboratory of the Processing Plant, MB Kolubara, PE EPS, on the calorimeter IKA 5003.

Results and discussion. Table 1 presents the statistical results of the heating values of all four analysed willow genotypes that were only air-dried.

The biomass of clone 1 (*Salix viminalis*) had the lowest mean caloric value, which was 17966.30 kJ/kg. In second place in terms of caloric value was clone 2 (*Salix alba* B-44) with a value of 18046.3 kJ/kg, followed by clone 3 (*Salix alba* 347) with 18237.6 kJ/kg. Clone 4 (*Salix alba* NS 73/6) is the clone with the highest average caloric value, which was 18246.8 kJ/kg. Mitić (2018) points out willows as the species that has found the greatest application in the economy precisely because of its wide ecological valence (resistance to extreme habitat conditions), with an average caloric value of 19300 kJ/kg of dry biomass [3].

In Table 1 it can be found that the minimum value was measured for clone 1 - (*Salix vininalis*), which was 17952.0 kJ/kg, while the maximum value had clones 3 (*Salix alba* - clone 347) and clone 4 (*Salix alba* – clone NS 73/6), each per 18274.0 kJ/kg. For the caloric value of the biomass of the studied genotypes, low values of the coefficient of variation were established (0.08–0.11%). According to the results of the analysis of variance (ANOVA), the mean values determined for the caloric value of the biomass of the four willow genotypes are statistically significantly different from each other (p = 0.0000). Based on this, it can be concluded that the caloric value of willow biomass depends on the genotype and that clones 3 and 4 are characterized by the highest energy potential, and clone 1 the lowest. Kijo-Kleczkowska et al. (2016) point out that the caloric value of willow *Salix viminalis* is 16824 kJ/kg [4], while Karampinis et al. (2011) point out that the calorific value of willow without drying is on a "dry basis" 18410 kJ/kg [5].

Table 1

Analysis of variance for the caloric value (kJ/kg) of willow genotypes biomass

Genotype (clone)	**N**	$\bar{X}$	$\bar{\bar{X}}$	**MIN**	**MAX**	**SD**	**CV, %**	**F**	**p**
1.*Salix viminalis*	9	17966.30 c	18124.3	17952.0	17983.0	13.54	0.08	579,79	**0.0000**
2. *Salix alba* B-44	9	18046.30 b		18028.0	18062.0	14.86	0.08		
3. *Salix alba* 347	9	18237.60 a		18209.0	18274.0	20.35	0.11		
4. *Salix alba* NS 73/6	9	18246.80 a		18209.0	18274.0	20.00	0.11		

Note*: Mean values with various letter designations within a column are statistically significantly different from each other at the 95% confidence level.*

** PC – Public Company*

** Forestry

*** Forest Administration

Based on the differences in the calorific value of coal and the mixture of coal and biomass of four willow clones (in the share of 5%, 10%, 15% and 20%), an overview of the results on the possibility of improving the calorific value of the tested coal with biomass is presented.

Table 2 provides the statistical results on the differences between the caloric value of various mixtures of coal and willow biomass according to the genotype (clone) and biomass share.

Table 2

Analysis of variance for differences in the calorific value (kJ/kg) of coal and coal mixture with willow biomass according to genotype and biomass share

Clone, % of biomass and coal	**N**	$\bar{X}$	$\bar{\bar{X}}$	**MIN**	**MAX**	**SD**	**CV, %**	**F**	**p**
I *Salix viminalis* -5%	9	440.22 f	669.56	175.0	647.0	169.39	38.48	3.54	**0.0000**
I *Salix viminalis* -10%	9	672.22 bcdef		488.0	899.0	145.38	21.63		
I -15%	9	741.22 abcde		381.0	1167.0	302.18	40.77		
I *Salix viminalis* -20%	9	824.56 abcd		379.0	1119.0	321.83	39.03		
II *Salix alba* B-44-5%	9	454.22 f	672.55	335.0	571.0	70.07	15.43		
II *Salix alba* B-44-10%	9	584.67 def		-21.0	1059.0	443.47	75.85		
II *Salix alba* B-44-15%	9	839.89 abc		599.0	1099.0	184.49	21.97		
II *Salix alba* B-44-20%	9	812.22 abcd		271.0	1226.0	388.32	47.81		
III *Salix alba* 347-5%	9	460.78 f	686.19	393.0	599.0	66.92	14.52		
III *Salix alba* 347-10%	9	552.44 ef		303.0	783.0	178.71	32.35		
III *Salix alba* 347-15%	9	804.22 abcd		569.0	1027.0	173.36	21.56		
III 347-20%	9	927.33 a		369.0	1294.0	393.76	42.46		
IV *Salix alba* NS 73/6-5%	9	640.89 bcdef	750.36	494.0	779.0	94.61	14.76		
IV *Salix alba* NS 73/6-10%	9	611.56 cdef		431.0	792.0	126.65	20.71		
IV *Salix alba* NS 73/6-15%	9	864.89 ab		341.0	1187.0	351.86	40.68		
IV *Salix alba* NS 73/6-20%	9	884.11 ab		449.0	1206.0	308.11	34.85		

Note: *Mean values with various letter designations within a column are statistically significantly different from each other at the 95% confidence level.*

The mean values representing the differences in the calorific value of coal and the mixture of coal with willow biomass ranged from 440.22 kJ/kg (clone 1 with a biomass share of 5%) to 927.33 kJ/kg (clone 3 with a biomass share of 20 %) depending on the tested genotype (clone) and biomass share. The minimum value was recorded for the difference between the calorific value of coal and the coal mixture with 10% biomass of clone 2 and was -21.0 kJ/kg, and the maximum - for the difference between the calorific value of coal and the coal mixture with 20% biomass of clone 3 (1294.0 kJ/kg). Mean (10–20%), high (20–40%) or very high (>40%) values of the coefficient of variation were found for the calorific value of the differences between the coal and the examined mixtures of coal with biomass. According to the results of the analysis of variance (ANOVA), the mean values determined for the differences between the calorific values of coal and the mixture of coal and biomass of four willow genotypes are statistically significantly different from each other ($p = 0.0000$). Based on the values of the arithmetic means of the means ($\bar{\bar{X}}$) we can conclude that the energetically most promising is clone 4 (*Salix alba* NS 73/6), and the least promising is clone 1 (*Salix viminalis*).

Based on the obtained results, it can be concluded that the improvement of the calorific value of coal with willow biomass depends on the proportion of biomass and genotype, so that coal mixtures with 15% or 20% of the biomass of each clone have the highest calorific value, and coal mixtures with 5% of the biomass of clones 1, 2 or 3 – is with the lowest caloric value. The exception is clone 4 (*Salix alba* – clone NS 73/6), for which it is necessary to indicate that the addition of only 5% of the biomass of this clone results in a significantly greater improvement in the calorific value of coal compared to the other investigated clones in the same proportion, which also indicates that clone 4 is the most energetically promising and that it is economically the most profitable to add 5% of the biomass of this clone to lignite to improve the calorific value.

CONCLUSION

Good knowledge of the very plant species and their application in the economy represents a bridge that connects two seemingly incompatible sides - ecology and economy. Production and application of biomass that would co-burn with coal and improve its calorific value while simultaneously saving coal itself in the process of power generation, would reclaim the soil, reduce ash disposal costs, reduce carbon taxes, and reduce greenhouse gas emissions. All of the above presents the path of decarburization to protect the environment.

It can be clearly concluded from all of the above that:

1. The caloric value of the mixture of coal and biomass, in addition to depending on the type of coal, also depends on the genotype and share of willow mass;
2. The basket willow, *Salix viminalis*, showed the lowest caloric potential compared to the white willow (*Salix alba) genotypes examined*;
3. Clone NS 73/6 of white willow, (*Salix alba)*, showed the highest energy potential compared to other clones;
4. Although the results show that the calorific value of the mixture of coal and biomass increases with an increase in the biomass share, from an economic point of view, it is most convenient to choose 5% biomass of clone 4 (*Salix alba,* NS 73/6) for co-combustion processes with lignite.

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