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CEREALS AS ENERGY SOURCES IN THE FUNCTION OF CIRCULAR ECONOMY

SUMMARY

The circular economy is an approach that integrates the economy, the waste management system and protects the environment. The goal of the circular economy is to optimize the existing system and increase welfare. The growth trend of alternative fuels is evident in the world from year to year, thanks to the development of new technologies for processing biological waste into energy sources. Commercial production needs to be economically and environmentally friendly so that biofuels from renewable sources are an adequate substitute for fossil fuels. In this study, two winter grains, wheat and rye, were examined, during 2018/2019 and 2019/2020, in order to obtain biogas from plant biomass. The results showed that wheat had a statistically significantly higher production of biomass and biogas compared to rye. Based on the analysis of variance, it can be concluded that there are highly significant differences in biomass yield in regard to the genotype ($F_{exp}=937.75^{**}$) and years ($F_{exp}=28.07^{**}$) of investigation. There is a strong positive correlation between biomass and biogas yields.

Keywords: wheat and rye, biomass, biofuels, correlations, economic and environmental profitability

INTRODUCTION

Wheat (*Triticum vulgare* L.) and rye (*Secale cereale* L.) are species that represent one of the most important and earliest domesticated grains in the Old World (Glamočlija et al., 2015). Wheat was grown in the world in 2019 on 216,000,000 ha, with an average grain yield of 3.55 t ha^{-1} and a total production of 766,000,000 t, and rye on 4,213,392 ha with average grain yields 3.04 t ha^{-1} and with production of 12.801.441 t (Faostat, 2021). On the territory of the

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Republic of Serbia, wheat is grown on an area of about 600,000 ha, with an average yield of 4.4 t ha^{-1} and production of 2,535.00 t, while rye is grown on average on an area of about 6,000 ha with an average yield of 2.6 t ha^{-1} and production of 13.000 t (RZS, 2021). The circular economy represents a new approach that integrates the economy and the waste management system, opens up innovative and more efficient ways of production with global efforts for sustainable development. The circular economy model is in stark contrast to the dominant linear economy that promotes the concept of production called "take (from nature), make (in the production process), use and discard (waste)." The circular economy promotes competitiveness, innovation, protects living environment and at the same time contributes to economic growth. It is based on several principles: that products be designed to be reusable after use, and that the energy used in production comes from renewable sources, all with the aim of reducing dependence on resources. Thanks to the development of new technologies for processing bio-waste into energy, the growth rate of the use of alternative fuels is growing significantly (Popovic et al., 2020a; 2020b; 2020c; Ikanovic et al., 2020; Milanovic et al., 2020; Rakascan et al., 2021). According to estimates by energy experts, in highly developed countries it is about 15% per year. Rakascan et al. (2019a) point out that the cultivation of energy crops helps the development of rural areas (production of raw materials), but also industrial production, which provides the possibility of greater employment in primary crop production and biofuel production. The term biogas means gas produced in anaerobic fermenters and controlled conditions, i.e. in biogas plants. A mixture of gases, whose volume consists of about two thirds of methane and one third of carbon dioxide, is called biogas. By aerobic fermentation, organic biomass is decomposed to carbon dioxide, while methane is obtained by anaerobic means. Methane is a fuel gas, and the goal is precisely its production and use as an energy source (Glamoclija et al. 2015; Popovic et al., 2020b).

Straw, as an agricultural by-product, represents dry grain stalks, after the separation of grain and chaff, and makes up half of the grain yield. After harvest, straw is often burned in the fields. This is the most irrational way of using straw because burning burns all the organic substance that the useful soil fauna would decompose into forms that future crops can use for their needs. Straw burning should be decided only if the wheat was infected with the pathogenic fungus *Fusarium* sp. and *Erysiphe* sp. (Glamoclija et al. 2015). In the case of true cereal varieties, which have lower stalks and are less pruned, the share of harvest residues in the total yield is 40-50%. With a grain yield of 5,000 kg ha^{-1}, 3,500-4,500 kg ha^{-1} straw can be obtained. According to the results of the research, which are stated by British authors, if the straw of cereals, grown only in the area of the eastern part of the Midlands, were used to obtain biofuels, the amount of obtained energy would cover about 1.5% of British consumption. However, the views of local farmers are explicit, and they insist that these secondary products be returned to the land by plowing or as manure, which has a far greater importance on soil fertility and further plant production. Finding the optimal

solution for the use of cereal straw should be the subject of further research, as Copeland and Turley (2008) point out. Straw can also be used to obtain liquid biofuels (ethanol) because it has large amounts of carbohydrates. Today, in addition to the requirements for fuel quality, there are increasing requirements for low exhaust emissions of toxic gases and obtaining fuel from renewable energy sources.

The aim is to produce new fuels on new technologies that offer significant potential in improving air quality and reducing gas emissions, all with the aim of protecting the environment and the impact on global climate change. However, the complete penetration of new technologies on the market is a long process, and some of the new technologies are still in the development phase and require significant investments until final application (Lakic et al., 2018; Ikanovic et al., 2018; Jankovic et al., 2017; 2019). The situation is similar in the field of fuel application technologies. All these circumstances force the world factors in the automotive industry and energy in general, to develop new types of fuels from renewable sources from biomass of agriculture and agricultural crops.

In the fight against current problems, last year, within the 21st conference on climate change held in Paris, a new global agreement was adopted, which has a much more ambitious plan than the previous one. 196 member states, including the Republic of Serbia, have committed themselves to the obligatory reduction of greenhouse gases, and the allowed rise in temperature to 1.5 ° C starting in 2020. The obligation of our country is to reduce emissions by 9.8% by 2030 compared to 1990. As an economically much weaker country, compared to developed European countries, Serbia lags far behind in terms of production and application of clean energy, although it cannot be disputed the fact that we have natural resources that should be used for the purpose of obtaining energy as they point out (Jankovic et al., 2017). The essence of converting harvest and all other plant residues into biofuels is not only obtaining as much energy as possible, but also applying a sustainable method of production from which everyone will benefit.

The aim of this study was to examine the possibility of using wheat and rye biomass as an energy source in the process of obtaining biogas.

MATERIAL AND METHODS
Experimental design

During 2018/2019 and 2019/2020, a field micro-survey was set up according to a random block system in 10 repetitions with the size of the basic plots of 10 m^2 (5 m x 2 m) in Dolovo (44° 54′ N, 20° 52′ E, 101 m a. s. l.) near Pancevo, on chernozem type land. The subject of the research were two winter cereals: wheat, variety Ilina (created at the Field and Vegetable Crops, Novi Sad) and rye, variety Tayo (KWS) and the examined parameters are productivity parameters: biomass yield and biogas yield. During the vegetation season, standard technological practices for growing winter cereals were applied. For the analysis of productive traits, samples were taken from the cut biomass at the stage of technological maturity. The technology of obtaining biogas from biomass was

performed in a biodigester, where the biomass was previously ground and inserted into a biodigester where fermentation and biogas production are performed. Since its inception *Biogas Energy* (company) has been involved in research into the possibilities of improving the supply of biomass for its needs in an environmentally, economically and energy sustainable way. Biogas yield was determined by analysis of wheat and rye silage in the laboratory of the Technical Faculty in Novi Sad and calculated on cubic meters per ton.

Statistical analysis

The analysis of the obtained experimental data was performed through analytical statistics with the help of the statistical package STATISTICA 12 for Windows (*StatSoft*). The obtained results are shown in the table. The significance of differences in mean values of the treatments was tested by the LSD test. Relative dependence was defined through correlation analysis (Pearson's correlation coefficient), and the coefficients that were obtained were tested at the 5% and 1% levels of significance.

RESULTS AND DISCUSSION

Meteorological conditions

Climatic parameters were obtained from the meteorological station in Pancevo the average monthly temperatures during the research years. City Pancevo is located in the Autonomous Province of Vojvodina, in the Republic of Serbia on the banks of rivers Tamis and Danube, in the southern part of Banat in a fertile valley at an altitude of 77 m (44° 54′ 02″ N; 20° 52 ′ 23″ E, 101 m asl). The South Banat administrative district extends in the northern part of Serbia, ie in the south-eastern part of the northern Serbian province, Vojvodina, (Pictures 1a, 1b) at 4,245 km^2.

a.   b.
Picture 1. City Pancevo in Serbia (a) and Pancevo in South Banat District (b).

Agricultural land accounts for 80.9%. Pancevo located 18 kilometers northeast of Belgrade. Pancevo is characterized by a temperate-continental climate, with an average perennial temperature of 11.3°C and precipitation 643 mm. Favorable conditions in the vegetation period have influenced the fact that a large part of the population is engaged in agriculture.
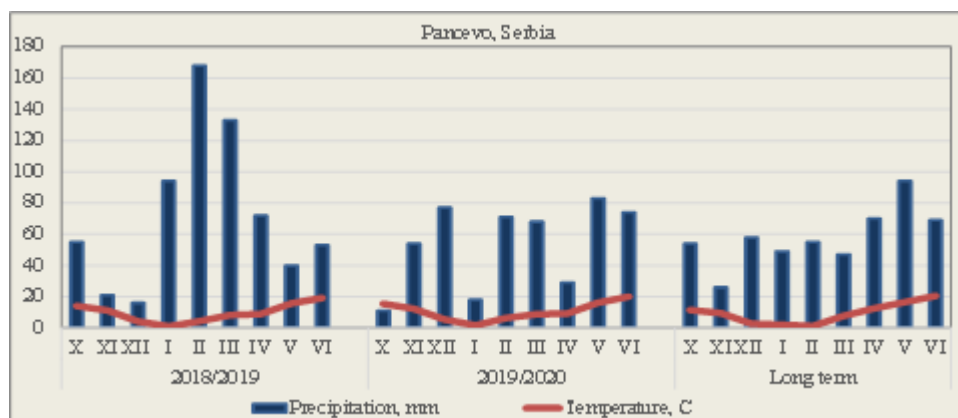

Figure 1. Precipitation and temperatures for the vegetation period of winter wheat and rye, Pančevo, Serbia

The amount of precipitation by months for the vegetation period of winter wheat in the years of testing, as well as the multi-year average (2010–2020) are shown in Graph 1. Mean multi-year temperatures for the vegetation period were 10.07 °C while the total vegetation precipitation was 522 mm. In the examined period, the average vegetation temperatures varied from 9.64 °C (2018/2019) to 10.5 °C (2019/2020) while the total vegetation precipitation varied from 485 mm (2019/2020) to 652 mm (2018/2019), (Figure 1).

Climate has a great influence on the growth and development of plants, so the elements of climate (light, heat, air and water) very often appear as a limiting factor (Popovic et al., 2012; 2020b; 2020c; Ljubicic et al., 2021). Significantly higher total precipitation for the vegetation period of winter cereals was in the first year of testing of 652 mm was higher compared to the precipitation for the multi-year average for the area of Pancevo by 130 mm while temperatures were lower by 0.33°C.

Yield of wheat and rye biomass

Based on the analysis of variance, it can be concluded that there are highly significant differences in biomass yield in regard to the genotype (F_{exp}=937.75[**]) and years (F_{exp}=28.07[**]) of investigation, Table 1.

The interaction of the investigated factors (Y x G) exhibits was significant affect in all cereals biomass yield (F_{exp}=9.88[*]), (p>0.05). (Table 1). The present results confirm the opinion of many authors that the traits analysed are genetically determined but are strongly modified by the environment and weather conditions (Popovic et al., 2020c; Rajicic et al., 2020a; 2020b).

Wheat had a statistically significantly higher average biomass yield compared to rye, p ≥05. The average biomass yield of the Ilina wheat variety was 2.79 t ha^{-1}, while the rye yield was 2.22 t ha^{-1}. Statistically significantly higher yield was achieved in the second year of the study 2019/2020 (2.56 t ha^{-1}) compared to the first year, 2018/2019 (2.46 t ha^{-1}), Table 2, Figure 2.

Table 1. The analysis of variance for the cereals biomass yield

Effect	Df	SS	MS	F	p-level
Intercept	1	75.350	75.350	72919.70**	0.000
Genotype	1	0.969	0.969	937.75**	0.000
Year	1	0.029	0.029	28.07**	0.000
Year x Genotype (YxG)	1	0.010	0.010	9.88*	0.014
Error	8	0.008	0.001		

[*]significant at 0.05; [**]significant at 0.01;

Table 2. Descriptive Statistics of wheat and rye biomass yield, 2018/19-2019/20

Parameters	Level of Factor		No	Biomass yield Mean	Biomass yield Std.Dev.	Biomass yield Std.Err	Biomass yield -95,00%	Biomass yield +95,00%
Total			12	2,5058	0,3039	0,0877	2,3126	2,6989
Genotype;G	Wheat		6	2,7900	0,0357	0,0146	2,7524	2,8275
Genotype, G	Ray		6	2,2216	0,0906	0,0370	2,1265	2,3167
Year, Y	2018-2019		6	2,4566	0,3455	0,1410	2,0940	2,8192
Year, Y	2019-2020		6	2,5550	0,2794	0,1140	2,2617	2,8482
G x Y	Wheat	2018-2019	3	2,7700	0,0435	0,0251	2,6617	2,8782
G x Y	Wheat	2019-2020	3	2,8100	0,0100	0,0057	2,7851	2,8348
G x Y	Ray	2018-2019	3	2,1433	0,0450	0,0260	2,0313	2,2553
G x Y	Ray	2019-2020	3	2,3000	0,0100	0,0057	2,2751	2,3248

LSD	Biomass yield		
	G	Y	G x Y
0.05	0.043	0.043	0.061
0.01	0.062	0.062	0.088

The interaction of the examined factors had a statistically significant influence on the yield of wheat and rye biomass. Average rye biomass yields were 2.14 t ha^{-1} (2018/2019) and 2.30 ha^{-1} (2019/2020) and were significantly lower than wheat biomass yields in 2018/2019 (2.77 t ha^{-1}) and in 2019/2020 (2.81 t ha^{-1}), Table 2, Figure 2.
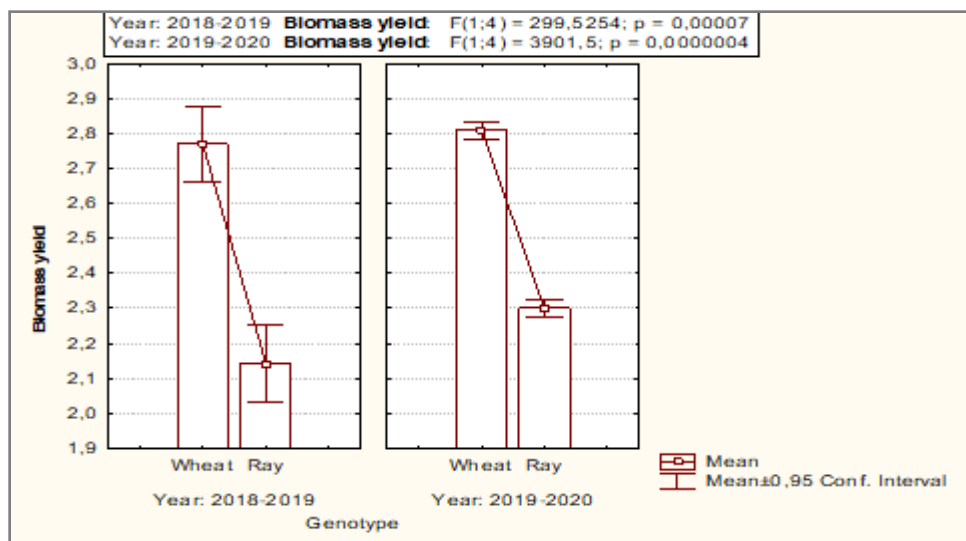
Figure 2. Wheat and rye biomass yield, Pancevo, 2018/2019-2019/2020

Biogass yield of wheat and ray

Based on the analysis of variance, it can be concluded that there are highly significant differences in biogas yield in regard to the genotype ($F_{exp}=3902.25^{**}$) and investigated years ($F_{exp}=5.32^{*}$). The interaction of the investigated factors (Y x G) exhibits was no significant affect in yield (p>0.05), Table 3.

Table 3. The analysis of variance for the wheat and ray biogas yield

Effect	Df	SS	MS	F	p-level
Intercept	1	102260	102260	56125.91**	0.000
Genotype, G	1	71098	71098	3902.25**	0.000
Year, Y	1	97	97	5.32*	0.005
Y x G	1	79	79	4.35^{ns}	0.070
Error	8	146	18		

^{ns}non significant; *significant at 0.05; **significant at 0.01;

The present results confirm the opinion of many authors that the traits analysed are genetically determined but are strongly modified by the environment and weather conditions (Popovic et al., 2020c; Rakascan et al., 2021).

Wheat had a statistically significantly higher average biogas yield compared to rye, p ≤05. The average biogas yield of the Ilina wheat variety was 368.89m^3 t^{-1} while the rye yield was 214.94 m^3 t^{-1}. Higher biogas yield was achieved in the second year of the 2019/2020 (294.76 m^3 t^{-1}) compared to the first year, 2018/2019 (289.08 m^3 t^{-1}) but the difference was not significant. The interaction of the examined factors did not have a statistically significant effect on the yield of wheat and rye biogas, Table 4, Figure 3.
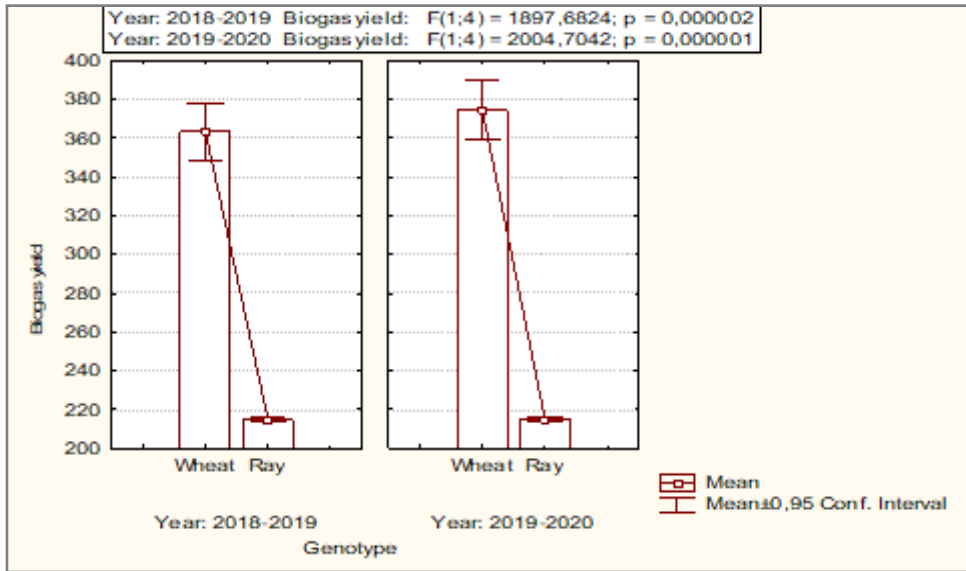
Figure 3. Wheat and rye biogas yield, Pancevo, 2018/2019-2019/2020

Table 4. Descriptive Statistics of wheat and rye biogas yield

Parameters	Level of Factor		No	Biogas yield Mean	Biogas yield Std.Dev.	Biogas yield Std.Err	Biogas yield -95,00%	Biogas yield +95,00%
Total			12	291,919	80,577	23,260	240,723	343,116
Genotype, G	Wheat		6	368,892	8,013	3,271	360,483	377,301
Genotype, G	Ray		6	214,946	0,438	0,179	214,486	215,407
Year, Y	2018-2019		6	289,078	81,588	33,308	203,456	374,700
Year, Y	2019-2020		6	294,761	87,223	35,608	203,225	386,296
G x Y	Wheat	2018-2019	3	363,480	5,906	3,410	348,806	378,153
G x Y	Wheat	2019-2020	3	374,305	6,142	3,546	359,047	389,563
G x Y	Ray	2018-2019	3	214,676	0,339	0,195	213,833	215,519
G x Y	Ray	2019-2020	3	215,216	0,383	0,222	214,262	216,170

L	Biogas yield		
SD	G	Y	G x Y
0.05	5.681	5.681	8.037
0.01	8.267	8.267	11.693

Correlations between tested parameters

The relationship between biomass yield and biogas properties in rye and wheat was presented using correlation analysis, using the Pearson linear correlation coefficient. A strong positive correlation between biomass and biogas yields was calculated (r = 0.98**), table 5.

Table 5. Correlations beetwen tested parameters

Parameter	Biomass yield	Biogas yield	Temperature	Precipitation
Biomass yield	1.00	0.98**	0.17[ns]	0.17[ns]
Biogas yield	0.98**	1.00	0.04[ns]	0.04[ns]

[ns]non significant; **significant at 0.01.

The use of correlation coefficient analysis in the wheat and rye, simplify dependable classification of bread wheat and rye, the identification of the superior genotypes and their relationship with bio morphological traits in future breeding programs.

Wheat genotypes reacted differently in the two growing seasons, giving high results in most of the traits that contribute directly to grain yield during crop years (Ristić et al., 2009; Popovic et al. 2020c; Mandić et al., 2020; Đurić et al., 2020; Mirosavljevic et al., 2018; 2019). Similar results were obtained in the research of Milanovic et al. (2019; 2020); Popovic et al., (2020c) and Rakascan et al. (2019a; 2019b; 2021).

The present results confirm the statement of many authors that the traits analyzed, and their correlations are genetically determined but are strongly modified by the nutrient status of the environment and weather conditions (Djekic et al., 2014; Lakic et al., 2018; Rajicic et al., 2020a, 2020b).

Grain yield is one of the most important and complex traits in plant breeding. Knowledge about crop development, growth and dry matter accumulation enables the appropriate selection of genotypes and field technology. Growing season, sowing date, variety and sowing date × variety interaction had significant influence on crop biomass at anthesis and grain yield of wheat and barley. Dry matter translocation was in positive correlation with dry matter content at anthesis. Dry matter accumulation across growing seasons had a typical sigmoid pattern in every combination of sowing date and variety. These results indicated that during the selection of small grain cereals, it is necessary to develop genotypes characterized by higher leaf number and increased biomass, i.e., genotypes that in optimal sowing dates, have an adjusted phenological development to the agro-ecological conditions of the Panonian plane (Mirosavljevic, 2015). The variety itself cannot give a high yield without the application of all agrotechnical measures, to which we strive for primarily due to the high wheat importance. Wheat yield depended more on sowing time, and the influence of sowing time, variety, and interaction of these two factors on yield were statistically significant. The highest yield was registered (8.87 t ha^{-1}), while the average yield achieved by this micro experiment was 8.46 t ha^{-1} (Veliborović

et al., 2020). Župunski et al. (2021) results indicate the specificity of the years, the locations, and the responses of the varieties to mycobiota associated with winter wheat grain. Swedish scientist MacKey (1966) pointed out that the yield is very relative term, and it is always determined by variety, ecological conditions and level of the sole production. Borojevic and Cupina (1969), by testing yield components in the case of different wheat genotypes, concluded that the greater number of various traits have more decisive role in yield making in the case of various genotypes. It is the result of interaction between traits within one genotype as well as between genotype and environmental factor.

CONCLUSIONS

The growth trend of alternative fuels has been evident in the world in recent years, thanks to the development of new technologies for processing bio-waste into energy sources.

Wheat had a statistically significantly higher average yield of biomass and biogas compared to rye. Based on the analysis of variance, it can be concluded that there are highly significant differences in biomass yield in regard to the genotype (F_{exp}=937.75**) and years (F_{exp}=28.07**) of investigation.

The average biomass yield of the Ilina wheat variety was 2.79 t ha^{-1}, while the rye yield was 2.22 t ha^{-1}. Statistically significantly higher yield was achieved in the second year of the study 2019/2020 (2.56 t ha^{-1}) compared to the first year, 2018/2019 (2.46 t ha^{-1}).

There was a strong positive correlation between biomass yield and biogas yield.

Circular economy is an approach that integrates the economy and the waste management system and is a great chance for the development of each country.

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