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Original scientific article

GENOTYPE BY YEAR INTERACTION EFFECTS ON SOYBEAN MORPHO-PRODUCTIVE TRAITS AND BIOGAS PRODUCTION

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Biodiesel and biogas are especially important sources of renewable energy in the world and in Serbia. Biodiesel is used as transportation fuel; biogas is used for production of electricity and heat. Soybean (*Glycine max* L.) grain is the primary source of vegetable protein for food and feed supplements, also accounts for much of the world's bio-oil supply. Due to the development of new technologies for processing agricultural waste into energy, the rate of increase in the use of alternative fuels is significantly increasing. The aim of this study was to determine the productivity of soybeans and the possibility of obtaining biogas from soybeans in divergent years, 2017-2019. Main effects were monitored, genotypes (G), years (Y) and genotype by years interaction effects (G x Y) and were used for evaluation of soybean genotypes in different environments. Soybean varieties were tested for mass of 1000 grain (MTG), plant height (PH), grain yields (GY) and biogas yield (BY). Stability of grain and biogas yield was determined to select best genotype. Results showed that genotype and years had a significant impact on all measured variables. In all tested years, the biggest GY and BY were at genotypes G1 (2.40–4.49 t ha^{-1}, and 461.00–641.00 m^3 ha^{-1}, respectively) and G3 (1.97–4.30 t ha^{-1}; i.e. 447.67–620.00 m^3 ha^{-1}). Genotype G2 had statistically significantly lower values for

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all tested parameters compared to other tested genotypes. Correlation analysis of some chosen traits showed different interdependence between measured variables depending on the year conditions. The results of this study pointed out that among best genotypes for production of grain and biogas were G1 and G3. From the results of this study it can be concluded that G x Y trials are important for evaluation of stability and choosing the most stable genotypes of soybean.

Keywords: soybean, genotype, grain yield, biogas yield, correlation

INTRODUCTION

Gyicine max (L.) Merr. is legume, thermophile C3 plant, originated from tropical and humid regions. According to the distribution areal and the length of the growing season, soybean varieties are divided into several maturity groups: 000 - varieties grown above 49° latitude and which are less sensitive to photoperiodism, 00 - varieties whose vegetation lasts 100-110 days, 0 - varieties whose vegetation lasts 110-120 days, I - whose vegetation lasts 120 - 135 days and II maturity group whose vegetation period under optimal conditions is 135 - 145 days. Group III maturity group of varieties grown below 15° N and are the most sensitive to photoperiodism (HRUSTIĆ *et al.,* 1998; POPOVIĆ, 2010; GLAMOČLIJA *et al.*, 2015). Soybean grain is the primary source of vegetable protein for food and feed supplements, and it accounts for large part of the world's oil supply (TUKAMUHABWA *et al.*, 2017; POPOVIĆ *et al.,* 2019). Soybean proteins contain all essential amino acids so that they are close in quality to proteins of animal origin. Depending on the hereditary basis and growing conditions, soybean grains contain on average 40% protein and about 20% oil (SINGH and HYMOWITZ, 1999; POPOVIĆ *et al.*, 2012; 2013; 2015a; 2019). Technical oil is increasingly used to produce liquid biofuels. Soybean straw is used to make pellets, and also, by use of complex technological procedures for producing of other biofuels (GLAMOČLIJA *et al.*, 2015; POPOVIĆ *et al.*, 2020).

However, in Europe it is mostly regarded as a protein crop (KURASCH *et al.*, 2017a). The areas in the world and in Serbia, in the 2017 were 123,551,146 ha and 201,712 ha, respectively, with yields of 2.75 t ha^{-1} and 2.28 t ha^{-1}; and total production of 352,643,548 t and 461,272 t, respectively. The variability of the examined parameters, growing area and grain yield in the world, measured by the coefficient of variation, ranged from 4.15% to 5.16% and recorded a growth trend trend at the rate of 2.52% and 3.32% (MILANOVIĆ *et al.*, 2020).

All legumes are an important source of protein, oil, fiber and micronutrients, and play a vital role in cropping cycles due to their ability to fix atmospheric nitrogen. Biological fixation of nitrogen (N) is considered more eco-friendly than industrial nitrogen fixation because the NH_3 produced in the former process is readily assimilated into organic forms by the plant. Biological nitrogen fixation (BNF) in legume nodules occurs with differentiated forms of *Rhizobia,* termed bacteroids, within specialized structures called symbiosomes, inside the host plant cells (VALENTINE *et al.,* 2011; KOSEV and VASILEVA, 2019a). In symbioses with soybeans live and form nodules *Bradyrhizobium japonicum*, *Bradyrhizobium elkani* and *Sinorhizobium fredi* (MARTINEZ-ROMERO and CABALLERO-MELLADO 1996). In this community, up to 180 kg ha^{-1} of nitrogen could be fixationed, per year.

The symbiotic nitrogen fixation as a result of the *Rhizobium* – legume association is part of the complex interactions between the host plant and the microsymbiont. Understanding the nature of specific genetic features that affect symbiosis and nitrogen fixation will lead to clarification of important biological processes of symbiosis and will contribute to better practical use of nitrogen-fixing legumes. There is no information on how many genes affect the nitrogen fixation properties in the host plant-bacteria relationship (PARRA-COLMENARES, 2003; KOSEV and VASILEVA, 2019b).

The most important breeding goals for introduction of new variety are the grain yield and protein content (SATO *et al*., 2014). The selection of suitable cultivars that give optimum and stable yields in a given environment and that reach full maturity at the appropriate time is even more demanding for soybean due to its high photoperiod sensitivity, which has a strong influence on the length of growing season. Furthermore, the growing season of soybean is also highly dependent on temperature conditions (KURASCH *et al.,* 2017a, b). The height of soybean plants is an important trait because of its possible plant falling, which reduces the yield and increases the possibility of pathogen attack. Higher plant height favours more number of fertile nodules, which results in higher production of pods per plant. The height of the plant to the first fertile node is a very significant feature on which the height of the yield directly depends (GLAMOČLIJA *et al.*, 2015).

The environment can have a crucial influence on soybean production in particular regions, even more so when production environments are different from optimum breeding environments (FLAJŠMAN *et al.,* 2019). The effectiveness of selection work is determined by the availability of valuable initial material for the creation of forms that are resistant to environmental stress factors (NAUMKIN *et al*., 2012). Selection of the best cultivars would be straight forward if there were no genotype-by-environment (GE) interactions (YAN *et al*., 2010). Soybean multi-environment trials (MET) are conducted annually worldwide in order to determine superior genotypes for specific regions of growing and to help growers to select the most promising cultivars (YAN *et al*., 2010). The aim of MET studies is also to obtain varieties, which would maximize the economic income. Ideal varieties should have high yielding ability and high stability (ASHRAF *et al*., 2010). Stability analysis of soybean cultivars is taking place worldwide in order to select appropriate genotypes for each particular growing region. Numerous authors use different yield stability statistics to evaluate performance of tested genotypes (YAN and RAJCAN, 2003), e.g. GGE biplot (MATEI *et al*., 2018; FLAJŠMAN *et al.,* 2019), regression (b), (LIMA *et al*., 2000), coefficients of variation (Cv) (POPOVIĆ *et al*., 2012), amongst others. Interestingly, however, all stability indices are relative to each study and determine the best genotype among tested cultivars. Therefore, a direct comparison between different studies by the same index is inadequate.

The soybean is one of the most important protein and oil crop in Serbia, and the annual soybean straw production (SSP) reaches 20 million tons. The province of Vojvodina is the main growing region of soybean with the yield accounting for more than 90% of the total in Serbia. This area produces abundant SSS every year, most of which were burned after harvest, which not only waste resource but also cause pollution to the air and the surroundings (POPOVIĆ *et al.,* 2019).

The production of biofuels from renewable sources is an alternative to the production of biofuels from fossil sources, but also a challenge at an environmental, socio-political, and technological level. In order to achieve economically sustainable production of bioethanol from ligno-cellulosic raw materials it is necessary to develop and implement new technological solutions. Commercial production should be economically and environmentally friendly so that renewable fuels can be an adequate substitute for fossil fuels. This would reduce the use of liquid and solid fuels of oil and coal, which, by combustion, release significantly higher amounts of gases that have harmful effects on the ecosystem (greenhouse effect). The importance of using bio-fuels also lies in the fact that many countries do not have large reserves of fossil fuels for their own needs and are forced to procure them in an unstable market (RAKAŠČAN *et al.,* 2019).

Biodiesel and biogas are two very important sources of renewable energy worldwide, and particularly in EU countries. While biodiesel is almost exclusively used as transportation fuel, biogas is mostly used for production of electricity and heat. The application of more sophisticated purification techniques in production of pure bio-methane from biogas allows its delivery to natural gas grid and its subsequent use as transportation fuel. While biogas is produced mostly from waste materials (landfills, manure, sludge from wastewater treatment, agricultural waste), biodiesel in EU is mostly produced from rapeseed, soybean, or other oil crops (BUŠIĆ *et al.,* 2018).

Anaerobic digestion is mostly associated with the treatment of animal manure (cows, pigs, chicken, etc.) and sewage sludge. However, in order to achieve higher biogas yields, today majority of biogas facilities digest manure with the addition of co-substrates (e.g. energy crops, organic wastes from agriculture-related industries, food waste, municipal bio-waste from households, etc.). In total, agricultural residues and animals manure represent together more than 80% of the potential row-material for biogas production (WEILAND, 2010). In 2014, biogas production (by volume) increased to approx. 58.7 billion Nm^3 (1.27 EJ; average energy density factor of 21.6 MJ/Nm^3; 0.3584 PW·h) (WBA, 2017). Europe and Asia dominate in biogas production, where Germany and China are leading producers, followed by the USA (WBA, 2017). In Europe, 49.8 % of the world biogas is produced, followed by 31.9 % in Asia, 16.7 % in Americas and 1.6 % in the rest of the world (WBA, 2017). The biogas sector in Europe is very diverse. Germany and UK are the two largest biogas producers in the EU. Germany generates 92 % of its biogas from agricultural crops and residues. In Europe, the majority of the biogas is used to generate electricity and/or heat. According to the European Biogas Association (EBA) statistical report (STAT. REPORT, 2017), the biogas production has greatly increased since 2011: production rose from 752 GW·h in 2011 to 17,264 GW·h in 2016. In Europe alone in 2016 biogas production increased 40 % (4,971 GW·h). In 2016, the largest increase of biogas production was observed in Germany (900 GW·h), France (133 GW·h) and Sweden (78 GW·h).

The biogas production is a well-known technology that brings many benefits, both for economy and environmental, because biogas is a renewable energy source that comes from cheap and environmentally friendly recycling of organic waste and it lowers the greenhouse gas emission. The biogas production is also a sanitation process that reduces pathogen microorganisms in organic waste, removes odours and flies and produces an organic fertilizer that brings economic benefits for the farmers (HOLM-NIELSEN *et al.,* 2009). The availability at low costs and ability to use the broad spectrum of feedstock makes biogas very usable fuel that can be used to produce heat, steam, electricity, hydrogen or even as transportation fuel (WEILAND, 2010).

The aim of this study is to determine the productivity of soybeans and the possibility of obtaining biogas from soybean grains obtained at the Dolovo locality, on chernozem soil type, in three divergent years.

MATERIAL AND METHODS

Experimental data

This study was conducted over a three years period (2017-2019) in Dolovo, it is situated in the Pančevo municipality, in the region of South Banat, in Republic of Serbia (44° 54′ 02″ N, 20° 52′ 23″ E, 76 m a.s.l.), on a chernozem soil type. The trial was set up as randomized complete block (RCB) design in three replications with three soybean genotypes (G1-Favorit, G2-Dukat and G3-Laura), Table 1. The size of the basic plots was 10 m^2. Sowing was performed in the last week of April in 2017, 2018 and 2019 to the depth of 5 cm and the plants density was 600,000 plants ha^{-1} for Favorit genotype and 450,000 ha^{-1} for Dukat and Laura. Standard technology for soybean cultivation was applied. Soil processing, pest and disease control was carried out according to standard procedures for conventional production. The harvest was done at stage of technological maturity. Samples from mowed biomass were taken to analyze the morphological characteristics (plant height - PH). The grain yield (GY) was also determined. The biogas yield was determined by analysis of soybean grains in the laboratory of the Faculty of Engineering in Novi Sad, according to the method of VDI 4630 and was converted to m^{3}t^{-1} (MILANOVIĆ *et al.*, 2020).

Table 1. Analyzed genotypes, tested locality, and soil type

Tested Genotypes		Geographical Position	Soil type	Breeders house (Owner) / Source	MG	LV	YR
G1	Favorit	44° 52′ 15″ N, 20° 38′ 51″ E, 76 m a.s.l.	Chernozem	Institute of Field and Vegetable Crops, Novi Sad, Serbia	000	95	2010
G2	Dukat			Delta Agrar-Selsem, Belgrade, Serbia	0	115	2013
G3	Laura			Institute of Zemun Polje, Belgrade, Serbia	I	130	2007 2019

MG - Maturity group; LV - Length of vegetation, YR - Year of release

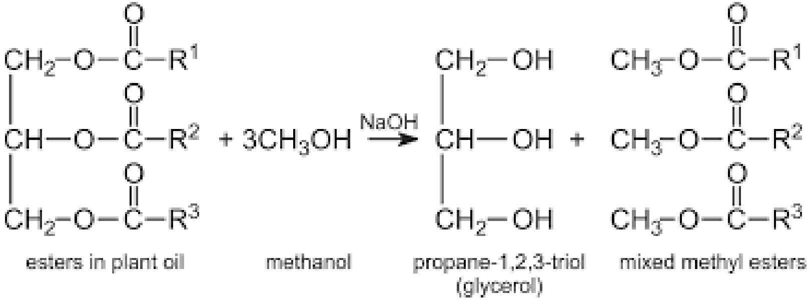
Statistical analysis

The experimental data obtained were analysed by descriptive and analytical statistics, with the statistical package STATISTICA 12 for Windows *(StatSoft).* Testing the significance of the differences between the calculated mean values of the examined factors (Genotype and Years) was done by using a two-factor model of variance analysis. All significance ratings were derived from the F-test and LSD test for a significance level of 5% and 1%. The relative dependence of the tested parameters for soybean was determined by the method of correlation analysis (Pearson's correlation coefficients), and the obtained coefficients tested by t-test for significance level of 5% and 1%.

Stability of tested parameters was determined in order to select best genotype by Cv. A coefficient of variation (Cv; in %) was applied to calculate the degree of variation of the statistical series. It is expressed as a percentage, by the formula: $CV = b \cdot 100 / \bar{X}$. The obtained results are presented in tables and figures.

Biogas production

Biogas is produced by the process of anaerobic digestion or fermentation, Picture 1. It is a biological process in which organic carbon is, by oxides-reduction processes, converted to the highest oxidation rate (CH_4). This process takes place in the absence of oxygen and is catalyzed by many microorganisms (CAKIĆ and STAMENKOVIĆ, 2009).



Picture 1. Methylolysis of biodiesel – reaction production of biodiesel (mixed methyl esters)

Meteorological conditions

Common observed variables which are objects of observation are temperature and precipitation, but wind, cloudiness and sun-shining, air pressure, humidity, as well as elements of greater impact on plants such as extreme storms, temperatures, snow and hail also can be observed. The World Meteorological Organization defines a period of 30 years as the standard timeframe for observing the climate of an area (PAVIĆEVIĆ, 1979; VRANIĆ, 2018; LAKIĆ *et al.*, 2019). In agro-climatic conditions of the observed area, production is conducting mainly in natural water regime (POPOVIĆ *et al.,* 2012; 2015b; 2016; 2019; JANKOVIĆ *et al.,* 2018; DONČIĆ *et al.,* 2019). Meteorological data were taken from Dolovo meteorological station. The data on the quantity and distribution of precipitation in the area of Dolovo, Serbia, 2017-2019 are shown in Figure 1.

Soybean is a warm climate plant but with enough moist. It needs relatively high temperatures. Temperature sums for very early varieties are 1700-1900ºC, for early varieties 2000-2200ºC, medium late varieties 2600-2750ºC and for very late varieties 3000-3200ºC. The sum of effective temperatures for soybean sprouting is 80ºC. The optimum temperatures for germination and sprouting of soybeans range from 20-22ºC, for the formation of reproductive organs 22-25ºC, for the formation and filling of seed of 21-23ºC, while temperatures above 40ºC have a very adverse effect on the growth and development of soybeans. In the pedo-climatic conditions of Vojvodina, soybean needs for water, during the vegetation period, range from 430 to 450 mm, daily needs 1-5 mm and by months are: in April 10-40 mm, in May 30-60 mm, in June 90-110 mm, 100-125 mm in July, 100-125 mm in August and 50-80 mm in September (VUČIĆ, 1981; POPOVIĆ, 2010; KOLARIĆ *et al.,* 2014; GLAMOČLIJA *et al.,* 2015).

Temperature and precipitation showed variation in the tested years. In a long time period, the average temperature was 19.9ºC and the total precipitation (in the soybean vegetation period) was 369.7 mm. In first year, the average temperature was 18.6ºC and total precipitation was 437.5 mm. During the second-year average temperatures was 19.4ºC while the total precipitation was 493.9 mm. During the third year, the average temperature amounted 18.9ºC while the total precipitation was 427.1 mm (Figure 1). Based on these data and the above-mentioned needs of soybean, it can be concluded that the best year for successful growth and development of soybean in experiment was the second production year.

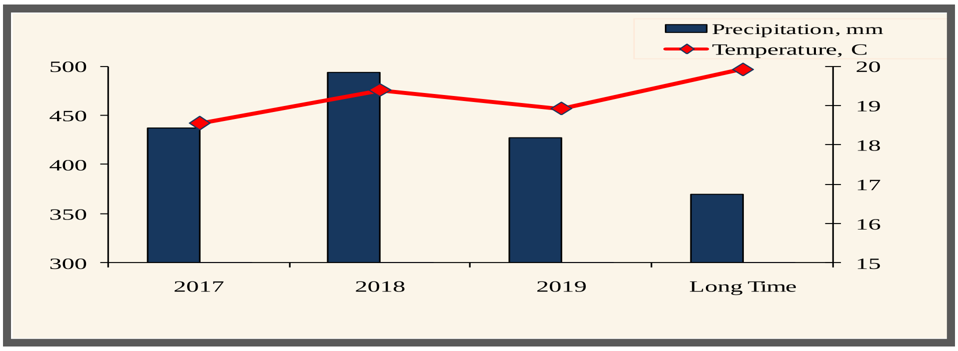


Figure 1. Average temperature (ºC) and total precipitation (mm) in soybean vegetation period at Dolovo, for 2017-2019 and long-time (LT) 30-years average values for Dolovo, Serbia

Precipitation, among meteorological factors, has a dominant influence on soybean production (STEVANOVIĆ *et al.*, 2017; TERZIĆ *et al.*, 2017; RAJIČIĆ *et al.*, 2019; POPOVIĆ *et al.*, 2019). The studied years varied both in the amount of rainfall during the growing season and in the schedule of them. In the studied years, precipitation values were higher than values for the long-term average by 67.8 mm, 124.2 mm, 57.4 mm, while temperatures were lower by 1.3ºC, 0.5ºC and 1ºC comparing 2017, 2018 and 2019 (Figure 1). In the observed years, the amount of precipitation was higher than the annual average, but the precipitation schedule was uneven. GLAMOČLIJA *et al.* (2015), state that an uneven precipitation schedule affects soybean growth and development as well as symbiotic nitrogen fixation. Soybean grain yield is greatly influenced by temperature and precipitation during vegetation. Large variations in external factors, such as extremely high temperatures, lack of water, inadequate mineral nutrition, strong wind intensity, and low relative humidity can cause plant stress (POPOVIĆ *et al.*, 2012; 2016; 2019).

Effects of climate change on agriculture are particularly significant in undeveloped and developing countries (such as Serbia), due to difficult economic situation and low investments in production improvement. A detailed study of current and future state of climate is the key for cost-effective and sustainable system of adaptation measures to climate change in the region such as Vojvodina, which is the most important agricultural part of Serbia (LALIĆ *et al.*, 2011). Climate change is increasing year by year. The more intense and frequent occurrence of extreme and adverse weather conditions will have the effect of reducing the potential yield and increasing of yield variability. Thermal stress negatively affects the fertility of individual crops. The effects of extreme weather can reduce soil fertility, impair its functions and lead to erosion (POPOVIĆ *et al.*, 2019).

RESULTS AND DISCUSSION

The studied morpho-productive traits of the tested soybean genotypes varied under the influence of environmental factors, which varied between the analysed years. Analysis of variance for the tested morpho-productive traits shows that genotype and year had a statistically significant effect on the obtained values, as same as the interaction of the studied factors for the mass of 1000 grains, grain yield and biogas yield (Table 2). The second examined year, 2018, had statistically significantly higher values for the most tested parameters compared to the first and third years, 2017 and 2019 (Table 3).

Table 2. Analysis of variance of soybean morpho-productive traits

Sources of variation	DF	SS	MS	F	F pr.
			Plant height		
Intercept	1	263045.40	263045.40	6637.593**	0.00000**
Genotype	2	369.41	184.71	4.661**	0.02338 *
Year	2	940.52	470.31	11.866**	0.00000**
G x Y	4	204.40	51.10	1.289*	0.31120
Error	18	713.30	39.60		
Total	26	2227.60			
			1000 grain mass		
Intercept	1	894712.03	894712.03	45069.45**	0.00000**
Genotype	2	1618.32	809.11	40.76**	0.00000**
Year	2	1742.31	871.11	43.88**	0.00000**
G x Y	4	67.00	16.80	0.84*	0.51532*
Error	18	357.34	19.90		
Total	26	3785.00			
			Grain yield		
Intercept	1	271.19	271.19	5496.103**	0.00000**
Genotype	2	1.43	0.72	14.521**	0.00000**
Year	2	21.99	10.99	222.785**	0.00000**
G x Y	4	0.08	0.00	0.408*	0.800623*
Error	18	0.89	0.05		
Total	26	24.39			
			Biogas yield		
Intercept	1	7568408.11	7568408.00	31327.15**	0.00000**
Genotype	2	16210.01	8105.10	33.55**	0.00000**
Year	2	151938.01	75965.11	314.45**	0.00000**
G x Y	4	1399.10	350.10	1.45*	0.25925*
Error	18	4349.11	242.01		
Total	26	173895.10			

*and** - statistically significant at 0.05 and 0.01; DF=Degrees of freedom, SS=Sum of squares, MS=Mean square, F=Variance ratio, F pr.= Probability value

The average plant height for all tested years was 98.70 cm. The years had a statistically very significant effect on this parameter. A statistically significantly higher plant height was recorded in 2018 (106.67 cm), compared to 2017 (92.55 cm) and 2019 (96.88 cm) (Figure 2a). The variation in plant height values between all tested varieties, measured by the coefficient of variation, was 4.59% and varied from 3.1% to 10.0%, for G3 and G1 genotypes, Table 3. Similar results in presenting differences in plant height between production years and genotypes are presented by POPOVIĆ *et al.* (2012) and DOZET *et al.* (2016).

The genotype also had a statistically very significant effect on plant height. The genotype G2 (93.66 cm) had statistically significantly lower values for the tested parameter compared to the genotypes G1-Favorit (102.44 cm) and G3-Laura (100.00 cm). The interaction of the studied factors (G x Y) had a significant effect on plant height (Table 2-3, Figure 2a).

Table 3. Average value for soybean morpho-productive traits, Dolovo, Serbia, 2017-2019

Genotype	Year	Plant height, cm	CV %	1000 grain mass, g	CV %	Grain yield, t ha^{-1}	CV %	Biogas yield, m^3 t^{-1}	CV %
G1-Favorit	2017	91.33±1.53	5.3	176.33± 5.13	7.2	2.40 ± 0.10	6.5	461.00 ± 11.5	8.0
G2-Dukat		90.67±3.05	4.1	163.00 ± 4.36	6.3	1.73 ± 0.20	5.3	395.33±5.03	5.8
G3-Laura		95.66±10.02	5.2	175.00 ± 5.00	7.8	1.97 ± 0.25	5.9	447.67±6.81	5.0
CV		2.93		4.28		16.69		7.99	
Average		92.55±5.79		171.44 ± 7.61		2.03 ± 0.34		434.66±30.9	
G1-Favorit	2018	112.00±3.00	8.8	196.33 ± 3.06	11.0	4.49 ± 0.26	13.0	641.00±10.2	8.9
G2-Dukat		99.00±9.00	16.0	180.33 ± 4.51	14.0	3.93 ± 0.21	6.3	593.33±15.27	5.9
G3-Laura		109.00±6.08	8.9	196.00 ± 4.36	7.3	4.30 ± 0.20	10.0	620.0±10.00	8.1
CV		6.38		4.79		6.71		3.87	
Average		106.67±8.15		190.88 ± 8.65		4.24 ± 0.31		618.11±23.18	
G1-Favorit	2019	104.00±5.56	5.7	191.67 ± 5.51	12.0	3.43 ± 0.20	12.0	550.00±26.46	8.4
G2-Dukat		91.33±1.53	5.3	170.00 ± 5.00	6.6	2.94 ± 0.21	6.2	593.33±15.27	5.2
G3-Laura		95.33±6.51	5.9	189.66 ± 2.08	6.8	3.30 ± 0.30	9.1	560.00±20.00	6.4
CV		6.68		7.25		7.87		6.01	
Average		96.88±7.80		183.77±11.07		3.23 ± 0.29		535.56±35.39	
G1-Favorit	2017-2019	102.44±9.54	10.0	188.11 ± 9.93	5.6	3.44 ± 0.92	30.0	550.67±79.43	16.0
G2-Dukat		93.66±7.05	5.1	171.11 ± 8.55	5.1	2.87 ± 0.97	38.0	495.11±86.75	20.0
G3-Laura		100.00±9.51	3.1	186.89 ± 9.95	5.8	3.19 ± 1.04	36.0	542.55±76.66	16.0
CV		4.59		5.21		9.02		5.67	
Average		98.70±9.25		182.03±12.07		3.17 ± 0.97		529.44±81.78	

Parameter	Genotype		Year		Genotype x Year	
LSD	0.05	0.01	0.05	0.01	0.05	0.01
Plant height	6.197	8.563	6.197	8.564	10.734	14.833
1000 grain mass	4.386	6.061	4.387	6.062	7.597	10.498
Grain yield	0.218	0.302	0.219	0.303	0.379	0.523
Biogas yield	15.302	21.144	15.303	21.145	26.503	36.624

The variation of 1000 grain mass values, between all tested varieties, measured by the coefficient of variation, was 5.21% and varied from 5.1% to 5.8%, for G2 and G3 genotypes (Table 3).

The average mass of 1000 grains for all tested genotypes and years was 182.03 g. The year had a statistically very significant influence on tested parameter. Significantly lower average values for the studied parameter were observed in 2017 (171.44 g) compared to 2018 (190.88 g) and 2019 (183.77 g). The genotype also had a statistically very significant effect on the mass of 1000 seeds. The G2-Dukat genotype (171.11 g) had statistically significantly lower average values for the tested parameter than the G1-Favorit (188.11 g) and G3-Laura (186.89 g) genotypes. The interaction of tested factors (G x Y) had a significant effect on plant height (Table 2-3, Figure 2b).

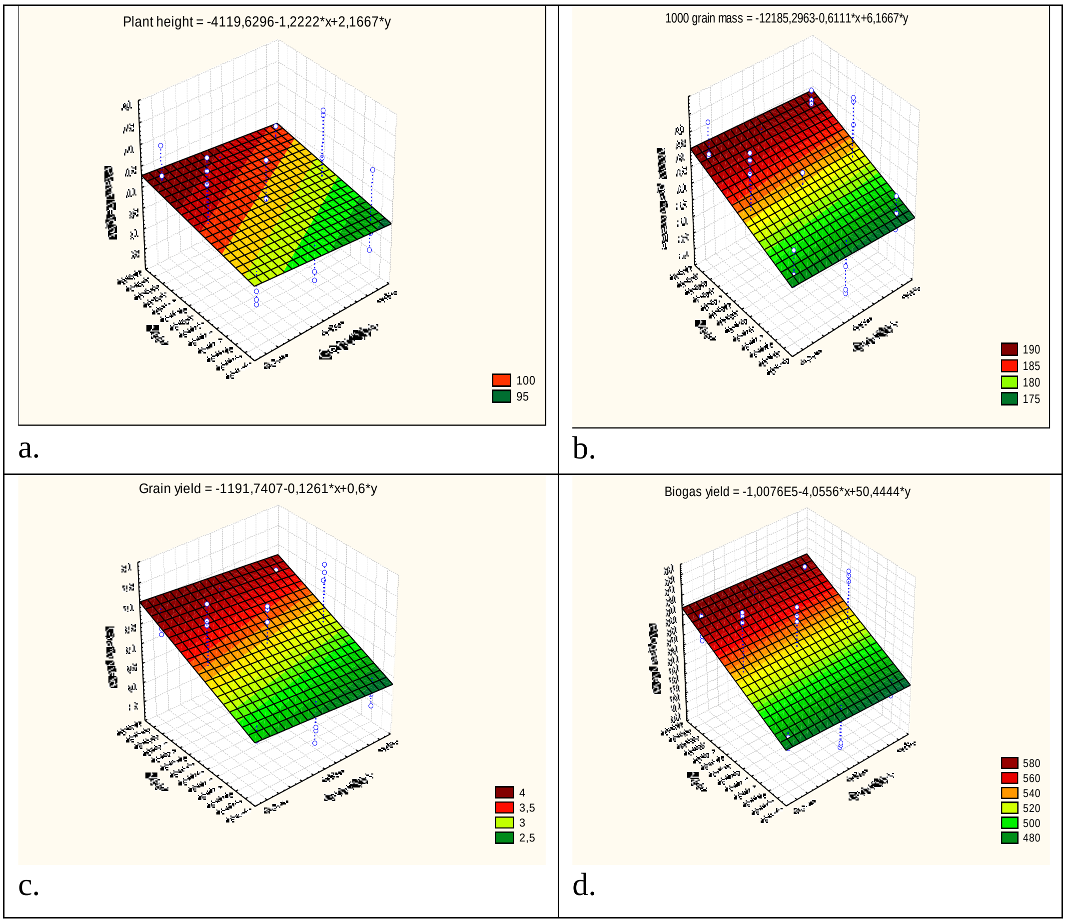


Figure 2. Influence of genotype and year on plant height (a), mass of 1000 grains (b), grain yield (c) and biogas yield (d), in period 2017-2019, on locality Dolovo, Serbia.

The average grain yield for all tested genotypes and years was 3.17 t ha^{-1}. Year had a statistically very significant impact on grain productivity. Significantly lower average values for the studied parameter were recorded in 2017 (2.03 t ha^{-1}) compared to 2018 (4.24 t ha^{-1}) and 2019 (3.23 t ha^{-1}). The genotype had a statistically very significant effect on grain yield. The G2-Dukat genotype (2.87 t ha^{-1}) had significantly lower average values for the tested parameter than the G1-Favorit (3.44 t ha^{-1}) and G3-Laura (3.19 t ha^{-1}) genotypes. The interaction of the studied factors (G x Y) had a significant effect on grain yield (Table 2-3, Figure 2c). The variation of grain yield values, between all tested varieties, measured by the coefficient of variation, was 9.02% and varied from 30% to 36%, for G1 and G3 genotypes (Table 3).

The average biogas yield for all tested genotypes and years was 529.44 m^{3}t^{-1}. The year had a statistically very significant impact on biogas productivity. Significantly lower average values for the examined parameter were recorded in 2017 (434.66 m^{3}t^{-1}) compared to 2018 (618.11 m^{3}t^{-1}) and 2019 (535.56 m^{3}t^{-1}). The genotype had a very significant effect on biogas yield. The G2-Dukat (495.11 m^{3}t^{-1}) genotype had significantly lower average values for the tested parameter than the G1-Favorit (550.67 m^{3}t^{-1}) and G3-Laura (542.55 m^{3}t^{-1}) genotypes. The interaction of the studied factors (G x Y) had a significant effect on biogas yield (Table 2, Figure 2d). The variation of biogas yield values, between all tested varieties, measured by the coefficient of variation, was 5.67% and varied from 16% (for G1 and G3) to 20%, for G2 genotype (Table 3).

Correlations of examined traits

The variability of morpho-productive traits and biogas yield of the tested soybean varieties was largely conditioned by the interaction between the varieties and environmental factors. The correlation coefficient of the traits examined is shown in Table 4. The correlation coefficient provides insight into the interdependence of traits and indicates properties that may be useful as indicators of behaviour of some important properties (JOHNSON *et al.*, 1955; POPOVIĆ *et al.*, 2012). In this study, positive significant correlations were found between plant height and 1000 grain mass (r = 0.83), plant height and temperature (r = 0.64), and between plant height and precipitation (r = 0.59), Table 4.

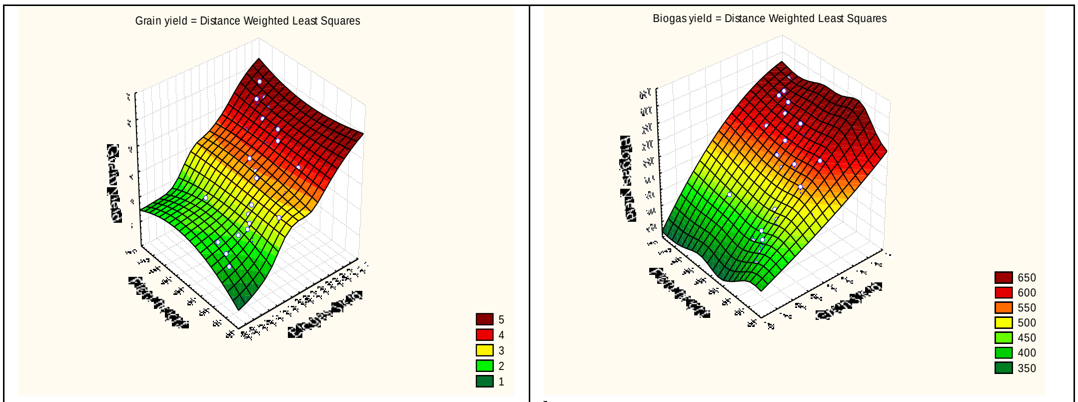
Table 4. Correlations of factors examined

Parameter	Plant height	1000 grain mass	Grain yield	Biogas yield	Temperature	Precipitation
Plant height	-	0.83*	0.76*	0.75*	0.64*	0.59*
1000 grain mass	0.83*	-	0.82*	0.87*	0.66*	0.47^{ns}
Grain yield	0.76*	0.82*	-	0.98**	0.95**	0.73*
Biogas yield	0.75*	0.87*	0.98**	-	0.93**	0.70*

^{ns} – non significant, *and** - statistical significant at 0.05 at 0.01

Positive highly significant correlation was obtained between grain yield and biogas yield (r = 0.98) (Figure 3a). Then, positive significant correlation were between grain yield and mass of 1000 grains (r = 0.82), grain yield and plant height (r = 0.76) and grain yield and precipitation (r = 0.73), Table 4.

A positive significant correlation was obtained between biogas yield and 1000 grain mass (r = 0.87), as well as between biogas yield and plant height (r = 0.75), Figure 3b, and biogas yield and precipitation (r = 0.70), Table 4.



a. b.

Figure 3. 3D effect of grain yield, plant height and biogas yield (a), and 3D effect of biogas yield, grain yield and plant height (b), 2017-2019, Dolovo, Serbia

By quantifying the impact of climate change on crop production, it is possible to form long-term plans for agricultural production in order to maintain a high and stable yield of key cultivated crops. Any change in weather conditions during the growing season influences the change in vegetation dynamics, water and nutrient uptake, and thus qualitatively and quantitatively properties of the final yield (JANČIĆ, 2015). The effects of climate change on agriculture include possible reduction and stagnation of yield and an increase the need for irrigation in dry years and areas (BRISSON *et al.*, 2010), as well as destabilization of yield due to various factors (TRNKA *et al.*, 2014; AL-HADI *et al.*, 2017; POPOVIĆ *et al.*, 2016, 2019; VRANIĆ, 2018; DONČIĆ *et al.*, 2019). Also, due to the increase in mean annual temperature, an extension of the development season can be expected, especially in northern geographical areas (EEA, 2017a; 2017b).

By the end of this century, under the SRES A1B climate scenario, in Serbia, for climate is expected to be warmer and drier and even more pronounced changes can be expected under the SRES A2 scenario. In the mid- and late- of century, more pronounced negative effects are expected, especially under scenario A2, so irrigation needs to be developed. Measures to mitigate adverse climatic effects, such as the introduction of new hybrids, drought tolerant varieties, mulching, overshadowing or other methodologies, are recommended. By applying modern measuring techniques and methods, along with other measures to mitigate the effects of drought, agricultural production in the territory of Serbia can be maintained and improved (STRIČEVIĆ *et al.*, 2015).

In experiment, there was a significant difference between the reaction of genotypes to different ecological conditions and on different treatments. Different reaction of inbred lines of maize to environmental factors caused high sum of the squares of individual interactions and their significant effect on total phenotypic variability which is reflected in high interaction in the overall variation of grain yield (BOŽOVIĆ *et al.,* 2018).

The environment can have a crucial influence on soybean production in particular regions, even more so when production environments are different from breeding environments. Therefore, soybean varieties must be evaluated in field trials at various locations in order to explore the duration of the growing period and capacity of yield, which is based on interactions between genotype and environment. Results of FLAJŠMAN *et al.* (2019) showed that variety and environment had a significant impact on all measured variables. In almost all tested environments the best varieties were ES Mentor (3425–5628 kg seed/ha) and NS Mercury (3468–5342 kg seed ha^{-1}). Correlation analysis of some chosen traits showed different interdependence between measured variables depending on the environment. The results of this study pointed out that among the seven tested varieties, ES Mentor, NS Mercury and NS Favorit were best genotypes (FLAJŠMAN *et al.,* 2019).

Biogas is a renewable energy source the production of which depends on availability and type of biomass (ANGELIDAKI *et al.,* 2009). By using biomass for energy production, productive land is destined to supply energy, not food or feed, which could have a huge impact on biodiversity and land use. However, the main problem is the food vs. fuel controversy. Biomass availability is one of the key factors for biogas production in the future. Harvest residues (soybean straw, corn-stover and sunflower stalk) are usually left in the field, but with the improvement of the pretreatment process along with soil protection, they could be used for the production of huge amounts of energy in the future (KOVAČIĆ *et al.,* 2017). Biofuels have been successfully produced in the world from rapeseed (JI *et al.,* 2014; WANG *et al.,* 2017), soybean (ZHU *et al.* 2013; ALVES ARAUJO *et al.,* 2017), miscanthus (KIESEL *et al*., 2017a; 2017b), maize, sunflower (KOVAČIĆ *et al.,* 2015). Due to the current fossil energy resources crisis (JI *et al*., 2014; WANG *et al.,* 2017), it has been proved that anaerobic digestion (AD), which convert organic matter in the oilseed rape straw - ORS into biogas and organic fertilizer, can be an economic and clean method. However, the ORS has high lignin content and carbon/nitrogen (C/N) ratio, which limits the anaerobic biodegradation process.

In Adana, the highest net energy yield of combustion and anaerobic digestion was recorded for OPM 9 in August at 344 and 203 GJ ha^{-1} respectively. At this location, the net energy yield of both combustion and anaerobic digestion decreased steadily, by 37 and 49% respectively, until final harvest in January. In Moscow, the genotypes with the highest net energy yield of combustion and anaerobic digestion in September were OPM 3 at 168 and 113 GJ ha^{-1} and OPM 6 at 143 and 92 GJ ha^{-1} respectively. While the net energy yield of OPM 3 decreased noticeably (−53% for combustion and −60% for anaerobic digestion), OPM 6 showed a net energy yield of combustion and anaerobic digestion of 172 and 99 GJ ha^{-1} respectively. In Stuttgart, the highest net energy yield of combustion was observed in October and of anaerobic digestion in September for OPM 6 at 370 and 259 GJ ha^{-1} respectively. Here, at final harvest in March, the energy yield of combustion and anaerobic digestion of OPM 6 was 275 and 154 GJ ha^{-1} respectively (KIESEL *et al*., 2017a; 2017b). In view of the world's energy scenario, it is important to seek exploration of alternative resources of energy. In Brazil there is great availability of biomass that isn't exploited, as in the food industry. The soybean processing industry has production losses that increase the availability of waste and consequently emitting methane gas into the atmosphere. The use of such waste for clean energy generation is advantageous (ALVES ARAUJO *et al.*, 2017).

CONCLUSION

Genotypes were very different by value yield during the observed years. The average grain yield for all tested genotypes and years was 3.17 t ha^{-1}. Year and genotype had a statistically significant effect on grain productivity. Grain yield varied from 2.03 t ha^{-1} (2017) to 4.24 t ha^{-1} (2018). In all years assessed, genotype G1 and G3 had the highest seed yield. Genotype G2 was highly interactive and had the lowest seed yield. Genotype G2-Dukat (2.87 t ha^{-1}) had a statistically significantly lower average value for the tested parameter than the G1-Favorit (3.44 t ha^{-1}) and G3-Laura (3.19 t ha^{-1}) genotypes.

Genotype, year and interaction of test factors (G x Y) had a statistically significant effect on biogas yield. The G2-Dukat (495.11 m^3t^{-1}) genotype had statistically significantly lower average values for the tested parameter than the G1-Favorit (550.67 m^3t^{-1}) and G3-Laura (542.55 m^3t^{-1}) genotypes. Grain yield had the largest impact on biogas yield. Since genotype have an influence on grain yield, tested genotypes also had a considerable impact on biogas yield. A positive highly significant correlation was found between grain yield and biogas yield.

Regarding lingo-cellulosic residues potential of soybean, that are of huge importance for Serbia, the situation is good. Serbia recognizes the biogas potential but still poorly utilized it compared to other EU states.

Biogas has to be produced on a sustainable way and that will bring benefit for all.

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UTICAJ INTERAKCIJE GENOTIP x GODINA NA MORFO-PRODUKTIVNE OSOBINE SOJE I PROIZVODNJU BIOGASA

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Izvod

Biogorivo i biogas su veoma važni izvori obnovljive energije u svetu i Srbiji. Biogorivo se koristi za transport, a biogas za proizvodnju električne i toplotne energije. Zrno soje (*Glycine max* L.) je glavni izvor biljnih proteina za ishranu, dodatak u ishrani takođe predstavlja veliki deo svetske zalihe bio-ulja. Zahvaljujući razvoju novih tehnologija za preradu poljoprivrednog otpada u energiju, stopa povećanja upotrebe alternativnih goriva značajno raste. Cilj ove studije bio je da se utvrdi produktivnost soje i mogućnost dobijanja biogasa iz soje u različitim godinama, 2017-2019. Praćeni su glavni efekti: genotip (G), godina (Y) i interakcija genotip x godina (GxY), i korišćeni su za procenu genotipova soje u različitim sredinama.

U sorti soje praćeni su: masa 1000 zrna (MTG), visina biljke (PH), prinosi zrna (GI) i prinosi biogas (BI). Stabilnost prinosa zrna i biogasa je određena sa ciljem da se odredi najbolji genotip. Rezultati su pokazali da su genotip i godina imali značajan uticaj na sve praćene parametre. U svim ispitivanim godinama najveći prinos zrna (GY) i prinos biogasa (BY) imali su genotipovi, G1 (2,40–4,49 t ha^{-1}; 461,00–641,00 m^3 ha^{-1}) i G3 (1,97–4,30 t ha^{-1}, 447,67–620,00 m^3 ha^{-1}). Genotype G2 imao je statistički značajno manje vrednosti za sve ispitivane parametre u poređenju sa ostalim testiranim genotipovima soje. Korelaciona analiza nekih izabranih osobina pokazala je različitu međuzavisnost izmerenih promenljivih u zavisnosti od uslova godine. Rezultati ove studije pokazali su da su najbolji genotipovi za proizvodnju zrna i biogasa bili G1 i G3. Iz rezultata ove studije može da se zaključi da su ispitivanja G x Y važna za procenu stabilnosti i za izbor najstabilnijih genotipova soje.

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