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PROCEEDINGS

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ECOLOGICAL MOVEMENT OF NOVI SAD

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FORAGE SORGHUM PERFORMANCE IN THE FUNCTION OF THE CIRCULAR ECONOMY

Abstract

With a circular economy, biodegradable waste - plant biomass can be reused as: compost, for soil fertilization, and for biogas production, as an affordable bioenergy source. In this study, the productivity of two hybrids of fodder sorghum, grown in Ilandza, Serbia, was examined. The results showed that there was a statistically significant difference between the tested hybrids, for leaf mass. A positive highly significant correlation was found between plant mass and leaf mass. Fodder sorghum is a species with C4 photosynthesis, which has a high degree of photosynthetic activity and has a high production of organic matter resulting in high biomass yield. Sorghum is a productive and cost-effective plant suitable for production feed but also for energy purposes.

Key words: Forage sorghum, biomass yield, morphological characteristics, circular economy, biodegradable waste.

INTRODUCTION

Circular economy, biodegradable waste can be reused in several ways - can be used as compost for fertilizing the soil, which is useful for agriculture, and can also be used for biogas production, affordable and clean energy source (Rakaščan et al., 2021). A special group of plants that meet the above requirements are species of the genus Sorghum, where the most significant place belongs forage sorghum. Sorghum is a cereal native to the central regions of Africa, where it was grown and used for human consumption seven thousand years ago. According to FAO data, in 2017, in the world sorghum (all forms) were grown on 44,771,056 ha, of which three percent is forage sorghum, and in Serbia on about 2,650 ha, mainly grain sorghum varieties. In the last decade, in our country, farmers have shown increasing interest in the cultivation of forage sorghum, Sudan grass and their hybrids for aboveground biomass, but also for varieties for grain production. In addition to the main product of sorghum, a significant amount of by-products remain and can be used in various ways (Ikanović et al., 2011; Glamočlija et al., 2015; Lakić et al., 2018), among other things as a bioenergy crop. Micro and macro nutrients improve the yield and the crop quality. Water stress is the major abiotic factor that limites plant production (Terzić et al., 2018; Popović et al., 2018; 2019; 2020). Forage sorghum can be grown in several sowing periods (main, subsequent and second sowing period), but at the same time have the ability to regenerate, where in depending on the growing conditions give two to three cuts per year (Glamočlija et al., 2015; Rakaščan et al., 2021). Sorghum yield varies depending on of sum and schedule precipitation and temperature. Forage sorghum has modest demands for water, and it is important for growing in arid areas. By growing forage sorghum in a regular sowing period, can be provided quality fodder for feeding ruminants, in continuity, from mid-July to early October. The choice of forage sorghum as pre-crop and tillage for its growth make it a good pre-crop for a different group of plants. Inter-crops (cabbage and annual forage legumes) are, in winter, of big importance for main and subsequent sowing period, because the land leaves in excellent condition, clear of weeds (Vučković et al., 1999; Erić et al., 1999; 2001). Basic processing (run time and depth) it is important factor for sowing and pre-sowing. Fertilizer quantities depend from specific agroecological conditions, land providing with nutritive elements and weather conditions. The estimated doses for sorghum are up to 120 kg ha^{-1} nitrogen, up to 130 kg ha^{-1} phosphorus and up to 130 kg ha^{-1} potassium (Lyons et al., 2019). Forage sorghum can be harvested as early as the stage of flower or milky ripening phase, without losing DM yield, allowing for timely planting of forage winter cereal, in a double crop rotation (Stanisavljević et al., 1996). In average agro-ecological conditions, with satisfactory agricultural technology, can be realized yield of green fodder above 100 t ha^{-1}, or dry matter above 20 t ha^{-1} (Djukić et al., 1995). The sorghum significance is great in industrial processing, in animal feed production, then as green fodder and for silage. Thanks to the development of new technologies for the processing of biological materials into energy products, the growth rate of the use of alternative fuels is growing significantly, and sorghum has a significant place in that. Because of the great importance of sorghum, the objective of this study was to investigate the effect of the genotypes of forage sorghum on the production of biomass.

MATERIALS AND METHODS

Sorghum experiments were conducted in 2018 by a random block system, in four replicates, with the size of basic plots of 10 m^2 in Ilandza (45°10′06″N, 20°55′06″E), South Banat in Vojvodina, in Republic of Serbia, on chernozem type soil. Two fodder sorghum hybrids were studied: NS Dzin (selected at the Institute of Field and Vegetable Crops, Novi Sad) and Bulldozer in locality Ilandza. Standard agro-technique for sorghum cultivation was applied. Autumn plowing was carried out to a depth of 25-30 cm, a pre-sowing preparation in spring. The application of the pruning, cultivating and harrowing surfaces has fine ground and aligned because sorghum seeds require good preparation of the sowing layer. Feed sorghum is a large nutrient consumer, and has higher fertilization requirements. During the experiment 160 kg N, 80 kg P_2O_5 and 60 K_2O per hectare were entered. All phosphorus and potassium, as well as 25% of nitrogen, are plowed in the autumn, and the remaining nitrogen in the spring during pre-sowing soil preparation. After the first harvest, the crop was harvested at 45 kg ha^{-1} N. The sowing was done at a 25 cm row spacing with 30 kg ha^{-1} of seed. The sowing was done at a 25 cm row spacing with 30 kg ha^{-1} of seed at the end of April, at a depth of 3 cm. 2.4 D herbicides were applied when the plants had 3 leaves. The mowing of the plants was carried out at the beginning of the tassel phase (second decade of July), to analyze the morphological traits of Biomass yield, t ha^{-1}, plant mass, g, and leaf mass, g. Freshly harvested biomass samples were taken in all replication.

All the plant data collected were subjected to statistical analysis of variance (ANOVA), using the Statistica 2012 statistical package, for the determination of significant treatment effects.

Meteorological conditions

Climatic conditions are very unpredictable (Bojović et al., 2019; Popović et al., 2018; 2019; Terzić et al., 2018). Total rainfall of vegetation period was 324.3 mm and was less than the perennial percipitation by 46.7 mm (371.0 mm), while the average monthly air temperature was 19.18 ° C and was less than the perennial temperature by 0.57 ° C (19.75 ° C), Figure 1.

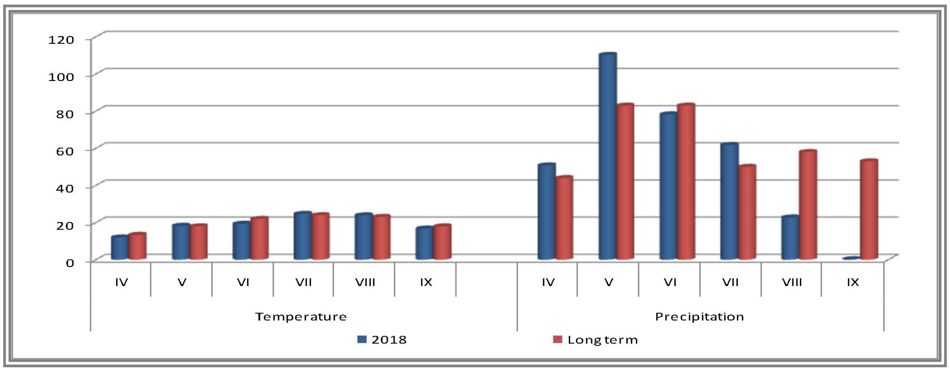


Figure 1. Precipitation (mm) and air temperature (° C) in 2018, Ilandza, Serbia

Morphologically-productive traits of sorghum

The morphologically-productive traits of the genotypes examined are presented in Tables 2.

Table 1. ANOVA for tested parameter of the sorghum genotypes

Parameter	D. of Freed.	SS	MS	F	p
Mass of plant					
Effect	1	8168.976	8168.976	293.387	0.000003
Intercept	1	41.953	41.953	1.507	0.265610
Variety	6	167.062	27.844		
Error	7				
Mass of leaf					
Effect	1	2910.845	2910.845	623.522	0.000000
Intercept	1	39.161	39.161	8.389**	0.027466
Variety	6	28.010	4.668		
Error	7	67.172			
Biomass yield					
Effect	1	21987.04	21987.04	16967.49	0.000000
Intercept	1	0.98	0.98	0.76	0.417925
Variety	6	7.77	1.30		
Error	7	8.76			

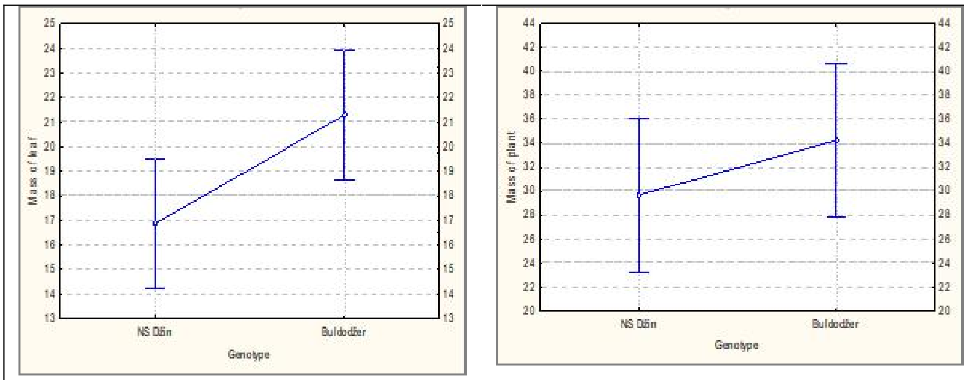
Table 2. Descriptive statistics for productive traits of the sorghum genotypes

Effect	Factor	No	Mean	Std.Dev.	Std.Error	-95,00%	+95,00%
Mass of leaf, g							
Total		*8*	19.075	3.977	1.095	16.485	21.665
Variety	*NS Dzin*	*4*	16.863	2.934	1.467	12.195	21.534
Variety	*Buldodzer*	*4*	21.288	0.855	0.427	19.927	22.648
Mass of plant, g							
Total		*8*	31.955	5.465	1.932	27.387	36.523
Variety	*NS Dzin*	*4*	29.665	7.057	3.528	18.436	40.894
Variety	*Buldodzer*	*4*	34.245	2.427	1.213	30.384	38.106
Biomass yield, *t/ha*							
Total		*8*	52.425	1.118	0.395	51.490	53.359
Variety	*NS Dzin*	*4*	52.075	1.464	0.732	49.745	54.404
Variety	*Buldodzer*	*4*	52.775	0.671	0.335	51.708	53.841

Parameter		Mass of leaves	Mass of plant	Biomass yield
LSD	0.5	3.739	9.130	1.969
	0.1	5.664	13.832	2.984

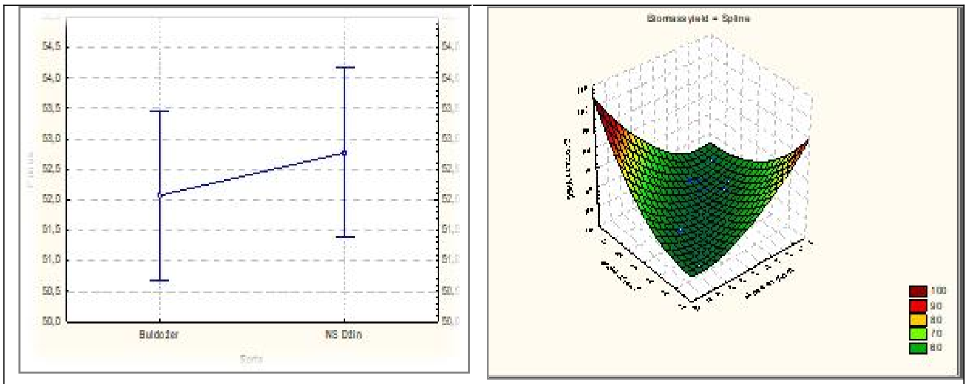
Both varieties achieved excellent performance and were very uniform in biomass yield. There was no statistically significant difference between the tested varieties for the tested parameter. The average leaf mass per plant was 19.08 g and ranged from

16.86 (NS Dzin) to 21.29 (Bulldozer), Graph 2a. The standard deviation averaged for leaf mass was 3.09, while the standard error was 1.09, Table 2. The genotype had no statistically significant effect on leaf mass per plant value, Graph 2a. The average mass of the plants was 31.96 g and varied from 29.67 (NS Dzin) to 34.25 (Bulldozer), Graph 2b. The standard deviation averaged for mass of plant was 5.46, while the standard error was 1.93, Table 2. The genotype had a statistically significant effect on values of mass of plants, Graph 2b.



a. b.

Figure 2. Effect of genotype on plant mass, a, and leaf mass, b



a. b.

Figure 3. Biomass yield (t/ha, a) and biomass yield in relation to mass of plant and leaves (b)

The average biomass yield was 52.43 tha-[1] and ranged from 52.08 (NS Dzin) to 52.78 (Bulldozer). The standard deviation for the biomass yield averaged 1.12, while the standard error was 0.39, Table 2. The genotype had no statistically significant effect on the value of the parameter tested, Graph 3a.

The correlations of the tested parameters are shown in table 3. A positive highly significant correlation was found between plant mass and leaf mass (r = 0.84).

Table 3. Correlations of tested parameters

Parameters	Biomass yield	Mass of plant	Mass of leaf
Biomass yield	1.00	0.28^{ns}	0.04 ^{ns}
Mass of plant	0.28 ^{ns}	1.00	0.84**
Mass of leaf	0.04 ^{ns}	0.84**	1.00
^{ns} - non significant; ** significant at 0.1			

A positive nonsignificant correlation was found between biomass yield and mass of plants, then biomass yield and leaf mass, tab. 3. In a field experiment conducted in Dalj in 2013, the estimated biogas yields fluctuated ranged from 4110 nm^3ha^{-1} to 10276 nm^3ha^{-1}. The highest biogas yield of 10276 nm^3ha^{-1} was estimated for the KWS Tarzan sorghum hybrid. The biomass and dry matter productivity may be considered highly relevant to less favorable environmental conditions, but estimate yields of biogas and methane should be considered with caution due to method of estimation- i.e. "flat rate" coefficients regardless the genotypes' herbage quality specialties (Mahmood et al., 2013; Prgić, 2018). The weight of a thousand grains of sorghum is 20g to 30g, and the hectoliter weight is around 60-70kg. The grain contains: 70% to 80% carbohydrates, 10% to 13% protein, 3% to 3.5% fat, 1.5% cellulose and 1.5% minerals. The length of sorghum vegetation ranges from 3.5 to 4.5 months (Kovačević and Rastija, 2009).

Ikanovic et al [28] in their research, point out that average plant height was 168.25 cm ranged from 158.75 cm (NS Dzin) to 177.75 cm (Buldodzer). According to Djukic et al. (1995) variety NS Dzin has excellent quality, average crude protein content of 9.6%, crude cellulose 41.2%, crude fat matter 0.4%, crude ash 6.9% and BEM 41.9%. Kanbar et al. (2019) in their study, used 12 genotypes of sorghum originated from different countries (five sweet, four for grain and three for forage). Analysis of variance showed significant differences between different types of sorghum for all tested traits. A positive significant correlation was observed between plant height, leaf number, leaf area, biomass yield, yields of cane and biogas, and the predicted bioethanol yield. The results clearly indicated that sweet sorghum can be grown in Germany and could maintains its superiority in biomass production and sugar yield over sorghum types for grain and forage. Sorghum is a productive and profitable plant species suitable for use in energy purposes. Improwing the technological process of producing biofuels from sorghum biomass and secondary products would lead to energy sources that have a much wider application. The advantage of these energy sources is that they come from renewable sources, which significantly reduces the dependence on fossil fuel imports that many countries do not have. The average biofuel yield was 143.73 cubic tons / tone and ranged from 142.70 cubic tone (Bulldozer) to 144.75 cubic tone (NS Dzin). The NS Dzin variety had a higher biofuel yield for 2.05 cubic tones or 1.44% (Ikanovic et al., 2014; 2018; 2019). The authors state that a second, positive effect would be a significantly lower emission of harmful gases into the atmosphere. Combustion of biofuels into the atmosphere releases as much carbon dioxide as plants consume during the year for photosynthesis processes, while releasing oxygen. The amounts of other harmful gases, which are released by combustion of these alternative fuels are also far less than those from fossil fuels. Therefore, the goal of cultivating these plants is to produce energy from renewable sources and to reduce the emission of CO_2 and other harmful gases into the atmosphere.

Circular economy, i.e. better management of biodegradable waste, would contribute to reducing greenhouse gas emissions and other types of pollution, create new, "green" jobs and save resources, which benefits the economy, environment and citizens of both Serbia and the whole world. Commercial production should be economic and environmentally friendly to make renewable fuels an adequate substitute for fossil fuels and at the same time protects and cares for the environment. In Serbia is six more power plants were built on biomass in rural areas, which produce electricity from agricultural waste. Thanks to the application of the principles of circular economy, and thanks to innovation and new technologies, they contribute to the reduction of GHG emissions.

CONCLUSION

Sorghum is a high-yielding plant species. Genotypes of forage sorghum NS Džin and Buldozder have excellent performance and high biomass yield. Sorghum is great importance, used in in industrial processing, in animal feed production, then as green fodder and for silage. Thanks to the development of new technologies for the processing of biological materials into energy products, the growth rate of the use of alternative fuels is growing significantly, and sorghum has a significant place in that. Sorghum biomass can be successfully used to produce biofuels, thus reducing the emission of harmful gases into the atmosphere and the greenhouse effect, as a basic factor in global warming and rising of temperatures.

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ПЕРФОРМАНСЕ КРМНОГ СИРКА У ФУНКЦИЈИ ЦИРКУЛАРНЕ ЕКОНОМИЈЕ

ИЗВОД

Циркуларном економијом, биоразградиви отпад-биомаса биљака може се користити као: компост али и за производњу биогаса, као приступачан извор биоенергије. У овој студији испитивана је продуктивност два хибрида крмног сирка, гајеног у Иланџи, Србији. Резултати су показали да постоји статистички значајна разлика између тестираних хибрида. Пронађена је позитивна значајна корелација између биомасе биљака и масе листа. Крмни сирак је врста са С4 фотосинтезом, има висок степен фотосинтетске активности и високу производњу органске материје што резултира високим приносом биомасе. Продуктивна је врста, погодна за производњу хране али и за енергетске сврхе.

Кључне речи: Крмни сирак, принос биомасе, морфолошке карактеристике, биоразградиви отпад, циркуларна економија.