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SOME BIOLOGICAL FEATURES AND BIOMASS QUALITY OF *Sorghum almum* UNDER THE CONDITIONS OF MOLDOVA

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Abstract

Taking into account the intensity and frequency of natural hazards, the expansion of areas with salinized and degraded soils in our region, it is necessary to mobilize, acclimatize and breed new crops that would ensure production in these severe conditions. The main objective of this research was to evaluate some biological features, the quality of green mass, the physical and mechanical characteristics of the dry biomass of the C_4 perennial grass species - Sorghum almum Parodi, under the conditions of the Republic of Moldova. We have found that, in the 3rd year, Sorghum almum resumed vegetation in the middle of April and, in the mid- June the plants were about 190-200 cm tall, being harvest for the first time. The green mass productivity was 28.3 t/ha at the first harvest, 17.2 t/ha at the second harvest and 15.3 t/ha at the third harvest, respectively. The annual feed productivity achieved 11183 nutritive units and 860 kg digestible protein. The calculated biochemical methane production potential of Sorghum almum substrate reached 279-316 l/kg organic matter. The specific density of the solid biofuel - briquettes was 788 kg/m^3, with 16.5 MJ/kg net calorific value. Sorghum almum can be used to obtain alternative green fodder for livestock, but also as multi-purpose feedstock for the production of renewable energy.

Key words: *biological features, fodder value of green mass, biochemical methane production potential, solid biofuel, Sorghum almum.*

INTRODUCTION

Taking into account the intensity and frequency of natural hazards, the expansion of areas with salinized and degraded soils in our region, it is necessary to mobilize, acclimatize and breed new crops that would ensure production in these severe conditions.

The genus *Sorghum* Moench, *Poaceae* family, includes 31 species, is native to Europe, Asia, North and South America, along with Australia. *Sorghum* species have recently gained popularity due to their numerous advantages, such as heat and drought tolerance, resistance to specific diseases and pests, being able to exploit the salty soils where the cultivation of cereals is more difficult. The adaptive nature of *Sorghum* species as C_4 plants and the better water use efficiency, their potential to produce higher tonnage of grains or green forage and their diverse uses make them a valued tool and one of the best choices for forage growers and dairy farmers demanding high quality feed stocks, also for food and other industrial uses, production of cellulose or renewable energy (Moraru, 2008; Roman et al., 2016; Wannasek et al., 2017; Ivanova et al., 2018).

Sorghum almum Parodi, native to Argentina, is an erect, robust, tussocky perennial grass with numerous tillers and thick short rhizomes which curve upwards to produce new shoots near the parental stool. The stem is solid and pithy, about 1 cm thick, sometimes reaching a height of 300 cm. The leaves are 1.3-3.8 cm wide and 45.7-81.3 cm long, generally glabrous except for the hairs near the ligule. The panicles are 15.2-61 cm long open, with branchlets mostly by four in whorls. It is predominantly cross-pollinated, but is also self-fertile. The caryopsis is brown to reddish-brown, 3-3.8 mm long, elliptic to obovate, dorsally compressed, the embryo - the length of the caryopsis, the hilum - round. Chromosome number is 2n = 40. *Sorghum almum* is a short-day plant, it propagates by seeds or by thick underground rhizomes, prefers soils from light loams to heavy clays, with a pH range from 5 to 8.5, tolerates drought and salinity but does not tolerate prolonged flooding. It is more tolerant to drought than maize, Sudan grass and Johnson grass, and can survive in areas receiving 200 mm of annual rainfall. Common names of this species, which can be found literature, are: Columbus grass, five-year sorghum, perennial sorghum - in English; sorgho d'Argentine - in French; Columbus grass - in German; sorgo almo - in Italian; sorgo negro, pasto colon - in Spanish; сорго щедрое, колумбова трава, сорго многолетнее - in Russian; сорго багаторічне, колумбова трава - in Ukrainian; iarba grasa, sorg peren, iarba lui Columb in Romanian (Popescu & Albu, 1970; Elizondo, 2004; Rakhmetov & Rakhmetova, 2009; Heuze et al., 2015; Ţîţei et al., 2015). In the former USSR, it has been researched since 1957, in the Central Asian republics, and then it became a popular research subject in Ukraine, from where it was introduced in Moldova, in the 70s of the past century. In the conditions of forest-steppe and in the Polissya region, Ukraine, the Columbus grass forms a bush of three to five productive stems of 230-300 cm in height, is characterized by high yields of biomass (75 t/ha fresh mass) and seeds (2.2 t/ha) and is moderately frost resistant (Rakhmetov & Rakhmetova, 2009). The green mass productivity of *Sorghum almum*, under irrigation conditions, in Uzbekistan, reached 211 t/ha (Avutkhonov et al., 2016).

The goal of this research was to evaluate some agro-biological features, the biochemical composition of the harvested green mass of perennial sorghum, *Sorghum almum*, as well as the biochemical methane potential of the green mass substrate, the physical and mechanical characteristics of dry biomass and briquettes.

MATERIALS AND METHODS

The cv. 'Argentina' of perennial sorghum, *Sorghum almum,* created in the National Botanical Garden (Institute) Chişinău, which was cultivated in the non-irrigated experimental plot of the Plant Resources Laboratory, N 46°58′25.7″ latitude and E 28°52′57.8″ longitude, served as subject of the research.

The green mass of three-year-old plants of *Sorghum almum* was cut manually for the first time in the middle of June, the second time - at the end of July and the third time - at the end of the September. The harvested green mass was weighed. The leaves/stems ratio was determined by separating leaves and panicles from the stem, weighing them separately and establishing the ratios for these quantities, samples of 1.0 kg harvested plants. For chemical analyses, the samples were dried at 65 ± 5°C. The dry matter or total solid (TS) content was detected by drying samples up to constant weight at 105°C; crude protein - by Kjeldahl method; crude fat - by Soxhlet method; crude cellulose - by Van Soest method; ash - in muffle furnace at 550°C; calcium concentration - using the atomic absorption spectrometry method and phosphorus - using the spectrophotometric method; acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL) have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200, the concentration of hemicelluloses (HC) was approximated from subtraction of the ADF from the NDF, while the concentration of cellulose (Cel) of each sample was estimated by subtracting the ADL from the ADF. The biochemical biogas potential (Yb) and the methane potential (Ym) were calculated according to the equations of Dandikas et al. (2014) based on the chemical compounds – acid detergent lignin (ADL) and hemicellulose (HC) values:

$$Yb = 727 + 0.25\ HC - 3.93\ ADL;$$

$$Ym = 371 + 0.13HC - 2.00ADL.$$

To produce solid fuel, the *Sorghum almum* plants were mowed at the end of the flowering stage (July) and were left to lie in swaths for drying directly in the field. The dry biomass was chopped and milled in a beater mill equipped with a sieve with diameter of openings of 10 mm. The following scientific research on biomass for the production of solid biofuel was carried out: the moisture content of the plant material was determined by CEN/TS 15414 in an automatic hot air oven MEMMERT100-800; automatic calorimeter LAGET MS-10A with accessories was used for the determination of the calorific value, according to CEN/TS 15400; the particle size distribution was determined using standard sieves; the cylindrical containers were used for the determination of the bulk density; the briquetting was carried out by using the special equipment; the mean compressed (specific) density of briquettes was determined immediately after removal from the mould, as a ratio of measured mass over calculated volume.

RESULTS AND DISCUSSIONS

We could mention that, under the conditions of the Republic of Moldova, in the third year of growth, the plants of *Sorghum almum* resumed growth in the middle of April; new shoots grew from the rhizomes formed in the underground part in the previous year. At the end of the first week after the resumption of growth, the plantlets were 3-5 cm tall and had 2-3 leaves. A more intensive growth and development rates of plants were observed in May. Thus, in the middle of May, the stems reached 60-65 cm in height and branching began. By the end of the month, the plants were already over 120 cm tall. In mid-June, the initiation of formation of the panicles was observed.

The results of our study concern the agro-biological features, the green mass yield and the leaves/stems ratio, depending on the harvesting period (cut) of the *Sorghum almum* plants (Table 1). It has been determined that, in the third year of growth, when the plants were cut for the first time in mid-June, they were 196 cm tall, with a moderate leaves/stems ratio, and the productivity reached 2.85 kg/m^2 of green mass or 0.67 kg/m^2 dry matter. Due to the favourable weather conditions in June-July 2018 y., with considerable amount of rainfall and moderate temperatures 22-25°C, the plants recovered well after the harvest. Thus, several new shoots developed and, at the end of July, the height of the plants was 160-165 cm and 1.72 kg/m^2 green mass were harvested, with reduced dry matter content (18.6%), but higher proportion of leaves (49%). After the second cut, the growth and the development of plants were slower in the August, but then they intensified and, until the end of September, the shoots reached a height of about 153 cm and 30% of the plants were in the stage of panicle development. The yield at the third cut was 1.53 kg/m^2 green mass or 0.41 kg/m^2 dry matter. The annual productivity from three harvests was 6.1 kg/m^2 green mass or 1.4 kg/m^2 dry matter, surpassing the productivity of maize by 35%.

Table 1. The yield and its structure depending on the harvest time of *Sorghum almum* plants

Harvest time	Plant height, cm	Stem, g		Leaf, g		Yield, kg/m^2	
		green mass	dry matter	green mass	dry matter	green mass	dry matter
First cut 13.06.2018	196	23.2	7.0	11.3	2.9	2.85	0.67
Second cut 27.07.2018	163	16.4	2.6	11.0	2.5	1.72	0.32
Third cut 24.09.2018	153	8.5	2.1	7.1	2.1	1.53	0.41

It is a well-known fact that the content of dry matter and its biochemical composition are important for the feed and energy value of natural fodder. The dry matter content in *Sorghum almum* green mass significantly differed in dependence of the harvest time; it was optimal in the green mass obtained after the first and third cuts and the lowest - after the second cut. It was determined that the biochemical composition of the dry matter also varied depending on the harvest time: crude protein varied from 51.0 to 141.9 g/kg, crude fats - from 19.6 to 34.5 g/kg, crude cellulose - from 336.8 to 396.3 g/kg, nitrogen free extract - from 348.0 to 442.7 g/kg, ash - from 76.7 to 138.8 g/kg (Table 2). The amounts of protein, fats and ash were high in the green mass obtained after the second cut and low – after the third cut. The concentration of carbohydrates: crude cellulose and nitrogen free extract, in the green mass obtained after the first and the third cuts was significantly higher in comparison with the green mass obtained after the second cut.

The content of nutrients and their digestiblity influence the feed and energy value of *Sorghum almum* plants. Therefore, 100 kg of green mass obtained at the first cut contained 19.3 nutritive units and 207 MJ metabolizable energy, at the second cut - 12.4 nutritive units and 131 MJ metabolizable energy and at the third cut - 23.2 nutritive units and 249 MJ metabolizable energy for cattle. The annual feed productivity achieved 11183 nutritive units and 860 kg digestible protein.

Table 2. The biochemical composition, the nutritive and the energy value of the *Sorghum almum* green mass

Indices	First cut	Second cut	Third cut
Crude protein, %	8.29	14.19	5.10
Crude fats, %	2.70	3.45	1.96
Crude cellulose, %	39.00	33.68	39.63
Nitrogen free extract, %	42.25	34.80	44.27
Ash,%	7.67	13.88	9.05
Nutritive units/kg fodder	0.19	0.12	0.23
Metaboliz. energy, MJ/kg fodder	2.07	1.31	2.49
Calcium, %	0.53	0.52	-
Phosphorus, %	0.18	0.32	-
Carotene, mg/kg fodder	45.59	30.34	24.00

Minerals and vitamins have a disproportionate effect on animal production relative to their low concentration in total diets. Calcium is closely associated with phosphorus in the animal body, they are vital for the skeleton and the function of nerve impulses, cellular energy transfer and lipid metabolism. The Ca/P ratio should be 2:1 since there is an antagonist relationship between the two minerals concerning uptake from the small intestine. It was determined that calcium content reached 5.2-5.3 g/kg dry matter, varying insignificantly depending on the harvest time, while the phosphorus content increased substantially from 1.8 g/kg dry matter, at the first cut, to 3.2 g/kg dry matter, at the second cut, the calcium/phosphorus ratios were acceptable for cattle diets.

Plant carotenoids are precursors of retinol - vitamin A, together with Vitamin E and polyphenols, are natural antioxidants in ruminant diets. Higher carotenoid concentrations in milk contribute to an improvement in the nutritional value of dairy products. It was found that, during the development of *Sorghum almum* plants, the amount of carotene decreased from 45.59 mg/kg fodder at the first cut to 24.00 mg/kg fodder at the third cut.

Several literature sources describe the nutritional performance of *Sorghum almum* plants. According to Heuze et al. (2015) the average feed value of fresh aerial part was: 17.5% dry matter, 10.0% protein, 2.5% fats, 33.6% raw cellulose, 68.8% NDF, 39.3% ADF, 5.2% lignin, 11.7% ash, 4.5 g/kg calcium and 4.1 g/kg phosphorus, 63.8% digestible organic matter, 10.8 MJ/kg digestible energy and 8.7 MJ/kg metabolizable energy. Amador and Boschini (2000) reported that the nutritional quality of whole plants during growth stages from 24 to 150 days after sprouting changed: 10.41-38.20% dry matter content, 25.97-7.7% protein, 13.40-7.46% ash, 50.58-75.05% NDF, 26.69-50.63% ADF, 26.49-43.25% cellulose, 20.89-28.70% hemicellulose and 2.82-7.51% lignin. The results obtained by Elizondo (2004) in Costa Rica, varied with advancing stage of regrowth from 56 to 84 days: 11.2-17.3% dry matter content, 15.02-12.47% protein and 67.67-69.56% NDF. Lanyansunya et al. (2006), studied the chemical composition of *Sorghum almum* in pure stand and intercropped with *Vicia villosa*, harvested at the age of 18 weeks, and found that pure *Sorghum almum* contained 8.7% crude protein, 6.7% ash, 70.0% NDF 38.1% ADF, 6.9% ADF, 31.2% cellulose and 31.9% hemicellulose, but in mixture with *Vicia sativa* - 9.6% crude protein, 6.9% ash, 69.7% NDF 32.2% ADF, 5.9% ADF, 26.4% cellulose and 37.4% hemicellulose. Alpizar et al. 2014 mentioned that harvested *Sorghum almum* plants contained 8.77% crude protein, 54.88% NDF, 35.08% ADF, 19.80% hemicellulose and 8.29 % ash, but the produced silage was characterized by pH 3.8, 7.92% protein, 60.70% NDF, 36.49% ADF, 24.21% hemicellulose and 9.01% ash.

Biomass is an important source for the production of multi-purpose renewable energy. Pytomass can be converted into biomethane using anaerobic digestion process. The stability and the productivity of biogas reactors are mostly influenced by biochemical composition, biodegradability and ratio of carbon and nitrogen of substrate. We would like to mention that the carbon and nitrogen ratio in the investigated substrates of *Sorghum almum* green mass ranged from 29.6 to 60.1, the C/H ratio was optimal in the green mass substrates from the first and the second cuts. It has been found that, depending on the harvest time, the plant cell wall content also varies and affects the methane potential (Table 3). The results show that the cellulose concentration ranged from 376 to 447 g/kg, hemicellulose - from 249 to 315 g/kg and lignin - from 45 to 62 g/kg, which are much larger amounts than in the green mass substrate obtained after the third cut. The calculated gas forming potential was 546-617 l/kg; the methane yield was 279-316 l/kg. The annual methane productivity achieved 4198 m^3/ha.

Mahmood et al. (2013) found that the specific methane yield of *Sorghum* substrate varied from 250 to 354 l/kg and the total methane yield - from 3924 to 6554 m^3/ha. Wannasek et al. (2018) determined that *Sorghum* biomass yield reached 20.67 t/ha and the methane yield was 6500 m^3/ha.

Table 3. The biochemical methane potential of the green mass substrate from *Sorghum almum*

Indices	First cut	Second cut	Third cut
Carbon/nitrogen	33.3	29.6	60.1
Lignin, g/kg	50	45	62
Cellulose, g/kg DM	390	376	447
Hemicellulose , g/kg DM	266	249	315
Biogas, l/kg ODM	597	617	546
Biomethane, l/kg ODM	306	316	279
Methane yield, m^3/ha	2035	1011	1152

Table 4. Some physical and mechanical properties of biomass and briquettes from *Sorghum almum*

Indices	*Triticum aestivum*	*Sorghum almum*
Particle size distribution		
<5mm	31.5	22.1
4-5mm	17.3	17.8
3-4 mm	15.2	18.4
2-3 mm	17.7	15.7
1-2 mm	12.4	17.5
1 mm	6.0	8.5
Biomass properties		
moisture content, %	11.6	9.9
ash content, %	4.93	4.96
gross calorific value, MJ/kg	17.4	18.3
bulk density 7-35 mm chaffs, kg/m^3	79	109
bulk density 10 mm chaffs, kg/m^3	90	121
Briquette properties		
specific density, kg/m^3	740	788
bulk density, kg/m^3	407	439
net calorific value, MJ/kg	15.5	16.5

Direct combustion of grass biomass is not practical and briquetting is the most common densification method used for solid fuel production. Our study showed that *Sorghum almum* milled chaffs had the lowest percentage of particles larger than 5 mm (22.1%) and the highest percentage of particles smaller than 2 mm (26.0%), in comparison with wheat straw, *Triticum aestivum* chaffs (Table 4), this fact had a favourable impact on bulk and specific density. We could mention that *Sorghum almum* biomass contained about the same amount of ash as wheat straw (4.96%). The bulk and specific density of briquettes from *Sorghum almum* was 439 kg/m^3 and 788 kg/m^3, but wheat straw 407 kg/m^3 and 740 kg/m^3, respectively. The net calorific value of *Sorghum almum* briquettes was 16.5 MJ/kg.

Under the conditions of Ukraine, Kurylo et al. (2018) mentioned that the yield of dry phytomass of *Sorghum almum* was 11–14 t/ha and the energy value was 3750-3810 kcal/kg. Plistil et al. (2005), reported that the density of briquettes of *Sorghum vulgare* was 800-870 kg/m^3, the same index was 600-840 kg/m^3 for *Phalaroides arundinacea* and 650-730 kg/m^3 for barley straw, the destruction force was 40-60 N/mm, 10–35 N/mm and 6-13 N/mm, respectively. The results obtained by Ivanova et al. (2018), for sweet sorghum briquettes, were as follows: 7.7% moisture, 3.9% ash, 70.8% volatile matter, gross calorific value 18.9 MJ/kg dry matter, net calorific value 17.7 MJ/kg dry matter, the specific density was 617.5 kg/m^3 and the mechanical durability was 90.5%.

CONCLUSIONS

1. *Sorghum almum* plants, in the third growing season, resumed vegetation in the middle of April and were characterized by intensive growth and development rate, high regenerative capacity after being cut, thus making it possible to mow them three times per season.
2. The green mass productivity reached 28.3 t/ha at the first harvest, 17.2 t/ha at the second harvest and 15.3 t/ha at the third harvest, respectively.
3. The harvested green mass contained 5.10-14.19% crude protein, 1.96-3.45% crude fats, 33.68-39.63% crude cellulose, 34.80-44.27% nitrogen free extract and 7.67-13.88% ash, the fodder value was 0.12-0.23 nutritive units/kg and 1.31-2.49 MJ/kg metabolizable energy for cattle.
4. The biochemical methane potential of *Sorghum almum* substrate reached 279-316 l/kg and the annual productivity 4198 m^3/ha.
5. The specific density of the briquettes from *Sorghum almum* was 788 kg/m^3, with net calorific value 16.5 MJ/kg.

We consider that *Sorghum almum* biomass may be used as alternative feed for livestock and as multi-purpose feedstock for the production of renewable energy.

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