Sorghum bicolor (L.) Moench. - Plant for the future in Moldavia agriculture (Romania) and for the human nutrition

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Abstract. In the climatic conditions of the Center of Moldavia (Romania), there are eight sorghum hybrids cultivated for grains (Arsky, Foehn, Albanus, Shamal, Kalatur și Armorik, Elan and Alimentar) in order to establish their adaptability to the conditions of the area, by taking into account the current problems of agriculture caused by climate change and the need to find a solutions to fight hunger and improve human health. This study focused on two directions, namely: identifying genotypes that achieve the highest productions and establishing food value and the benefits of sorghum grains on human health by analysing the physico - chemical composition of the grains, by determining the mineral content of the grain and by determining the composition in amino acids. The grain production had ranged from 8623 kg/ha to 11181 kg/ha. This production had characterized by a protein content between 8.84 % and 12.80 %, in lipid content between 3.39 % and 4.15 %, in raw fibre content between 2.15 % and 3.95 % and the starch content was between 66.70 % and 74.66 %. The analysed mineral content of the sorghum samples has the following values (mg/100g a.s.): phosphorus - 280 - 330; potassium - 520 - 610; calcium - 2.4 - 3.9; magnesium - 260 - 290; iron - 11.6 - 18.9; zinc - 1.94 - 2.42; copper - 0.23 - 0.36; manganese - 1.60 - 1.97. Analysing the amino acid composition of sorghum samples it can be said that the samples contain all the essential amino acids, in concentrations that, some of them, exceed the recommended daily dose (FAO/WHO/UNU): leucine, isoleucine, histidine, valine. Also the analysed sorghum seeds add an important content of methionine, threonine and phenylalanine.

Key words: climatic change, genotypes, mineral composition, grain sorghum, yield

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1 Introduction

Sorghum (Sorghum bicolor (L.) Moench.) has long been considered a "miracle culture", solving many problems that the planet has, which is increasingly populated and hungry due to global warming and in continuous search for solutions for obtaining bioenergy.

The genus Sorghum belongs to the family Poaceae (Gramineae), the subfamily Panicoideae, the tribe Andropogoneae, the subtribe Sorghinae [1]. The genus Sorghum contains a very diverse group of plants, which made it very difficult to classify sorghum varieties in domesticated and wild [2]. It originates from North - East Africa and was first cultivated 4000 years ago [3].

Sorghum is a cereal of high importance, being in fifth place in the world after the production of grains (57.6 million tonnes) after corn, wheat, rice and barley [4]. It has a great development due to its use in human nutrition, especially in the semi-arid areas of the world, where pedoclimatic conditions offer limited conditions for agriculture. Such situations are mainly in Africa, Asia and Latin America, areas that are frequently affected by drought [5], here sorghum is one of the most important crops representing the main source of energy and nutrition for people [6]. In western countries, such as the United States, Mexico and Australia, sorghum is mainly grown for animal feed, but there is a growing interest in its use for biofuel production, as well as for use in human nutrition, having given its chemical composition, which is beneficial for the development of healthy and functional foods [7].

The agronomic importance of sorghum culture is given by the resistance to drought and to the high temperatures, which gives the adaptability of this plant in the tropical and subtropical areas, in the context of the climatic changes of desertification of some areas of the globe. In addition to its high tolerance to drought and high temperatures, sorghum also has the advantage of its cultivation at high altitudes and in saline - alkaline and inert soils. These advantages are due to the fact that sorghum has a well-developed root system and the leaves are protected by wax [3]. The species can grow under the conditions of precipitation amounts below 100 mm precipitation / growth cycle, the critical drought period is about 20 days shorter than in maize (27 days in sorghum and 46 days in maize), and pollen can withstand high temperatures of 45 -50 °C, while corn pollen resists up to 35 - 40 °C. Another advantage of sorghum culture is its resistance to disease and pests. Also, sorghum has low requirements for nutrient requirements, having a well-developed root system, it allows it to extract all the nutrients it needs from the soil.

In addition to its agronomic benefits, sorghum is very nutritionally valuable. Sorghum beans can be an excellent source of starch, protein, sugar, fibre, being much cheaper compared to other crops. Grains are gluten-free, rich in starch and in nutrients and, most importantly, contain a wide range of bioactive phenolic compounds [8]. The unique phenolic profile gives sorghum a number of benefits to human health, such as reducing oxidative stress and preventing cancer [9].

Due to its superior agronomic properties and its potential to be used in human health, sorghum has attracted considerable attention in recent decades from researchers and the food and drug industries. With the ever-increasing change in consumer demand for healthy, plant-based foods, sorghum has enormous potential for exploitation and development in healthy and functional foods and food additives [10, 11]. The nutritional composition of sorghum varies depending on the cultivated hybrid. In general, carbohydrates (starch and non-starch polysaccharides), proteins and lipids are the main compounds of the grain [12]. On average, 100 g of sorghum contains about 72.1 g of carbohydrates, 12.4 g of water, 10.6 g of protein, 6.7 g of fibre and 3.5 g of fat and provides approximately 1.377 kJ of energy [13]. Starch is the dominant carbohydrate and varies depending on the hybrid, from 32.1 g to 72.5 g to 100 g of grains [14]. Sorghum is a rich source of fibres, because non-starch carbohydrate in sorghum is composed of insoluble fibres (75 % to 90 %) and soluble fibres (10 % - 25 %), which are found in the walls of the pericarp and endosperm cells - 15 g to 100 g of berries [15].

Sorghum protein can be broadly divided into prolaminic proteins (kafirins) and non-prolaminic proteins (globulins, glutelin and albumin). Kafirins are the main proteins, accounting for 70 % of the total protein, while albumin, glutelin and globulin represent the rest [16]. Sorghum beans are rich in glutamic acid, proline and leucine [17]. Sorghum proteins have low digestibility. Kafirins have high degree of polymerization and extensive disulphide bridges that are resistant to enzymatic digestion in the digestive tract and strong interaction with tannins and starch also impedes protein digestion [18]. These characteristics make sorghum a promising source of food for people suffering from obesity and diabetes [19].

Lipids from sorghum are mainly unsaturated fatty acids, being represented in particular by oleic, linoleic, palmitic, linolenic and stearic acids [13].

Sorghum is also an important source of vitamins and minerals. Vitamin B complex (pyridoxine, riboflavin and thiamine) and some fat-soluble vitamins (A, D, E and K) are the main vitamins in sorghum, and potassium, phosphorus, magnesium and zinc are the main minerals [13, 15].

Considering the current problems of agriculture caused by climate change and the need to find a solutions to fight hunger and improve human health, in the climatic conditions of the Center of Moldavia (Romania), we have conducted studies on eight sorghum hybrids cultivated for grains (Arsky, Foehn, Albanus, Shamal, Kalatur și Armorik, Elan and Alimentar). This study focused on two directions, namely: identifying genotypes that achieve the highest productions and establishing food value and the benefits of sorghum grains on human health by analysing the physico - chemical composition of the grains.

2 Methodology

In the pedoclimatic conditions from the Agricultural Research and Development Station Secuieni (Center of Moldova), researches were carried out regarding the adaptability of some grain sorghum hybrids to the conditions of the area and their influence on its production and quality. The experiments were performed on a typical Cambodian chernozem soil type, characterized as being normally supplied with mobile phosphorus (P_2O_5 - 39 ppm), and mobile potassium (K_2O - 161 ppm), moderately supplied with nitrogen (nitrogen index of soil: 2.1), weak acid (pH: 6.29) and weakly fertile (humus content 2.3 %) and in extremely adverse climatic conditions to agricultural crops. Both years of experimentation (2018 and 2019) presented during the vegetation period climatic conditions characterized as very dry and warm.

The experience was monofactorial, the factor being the sorghum hybrid for grains, and its placement in the field was carried out following the randomized blocks method, in three repetitions. As far as the experimental data are concerned, they were processed by statistical methods specific to the monofactorial experiences, and their interpretation was made by the variance analysis. The biological material came from the companies Euralis Seeds (Arsky, Foehn, Albanus, Shamal, Kalatur and Armorik hybrids) and from the Porumbeni Institute of Phytotechnics (Elan and Alimentar hybrids). The technology performed in the experimental field was the one specific for the pedoclimatic conditions in the Center of Moldova. The sowing distribution was 300000 Gg/ha and the precursor plant was the sunflower.

The sorghum berries have been analysed in 2018 - 2019 period from a physical, chemical and nutritional point of view, using modern methods of analysis, apparatus and equipment for analysis, measurement and processing specific to raw materials and products

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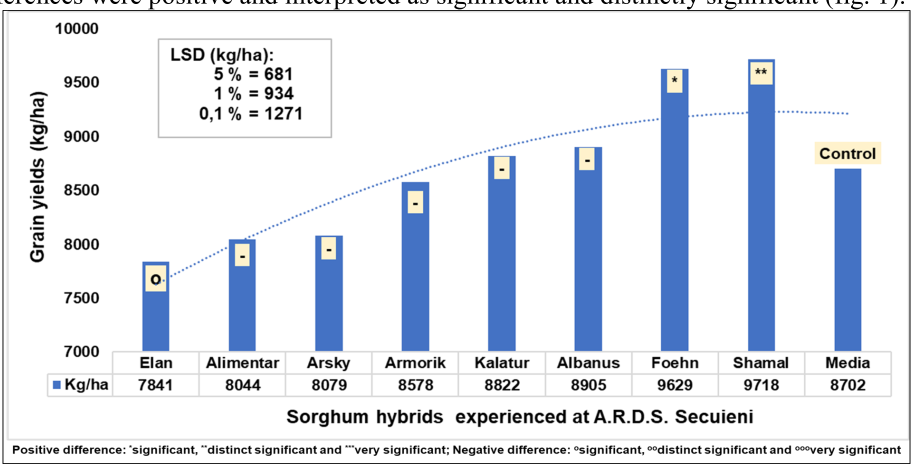
3 Results and discussions

The production results obtained under the conditions of A.R.D.S. Secuieni showed that sorghum, although it suffered during the vegetation period from unfavourable climatic conditions, showed adaptability and the obtained productions were substantial.

The average production (2018 - 2019) obtained at the sorghum showed great variations depending on the hybrid and was between 7841 kg/ha, as recorded in the variant sown with the Elan hybrid, and 9718 kg/ha, production recorded in the variant sown with Shamal hybrid. For comparison, we used the average of the experience as a witness, and the differences obtained in relation to this were statistically ensured in three of the variants, namely: in the variant sown with the Elan hybrid the difference was negative and interpreted as significant, and in the variants sown with the Foehn hybrids and Shamal, the differences were positive and interpreted as significant and distinctly significant (fig. 1).



LSD means Least significant difference (For positiv values - Differences larger than LSD 5% level are significant and are indicated with *, differences larger than LSD 1% level are distinctly significant and are indicated with ** and differences larger than LSD 0,1% level are verry significant and are indicated with *** and for negativ values the $^{*,\,**,\,***}$ is replaced with $^{O,\,OO,\,OOO}$.

Fig. 1. Grain yields obtained from sorghum under pedoclimatic conditions of the A.R.D.S. Secuieni, average 2018 - 2019

In order to identify hybrids with high dietary value, the samples collected from the experimental field were analyzed and the results obtained indicated large variations of the physical and chemical indices depending on the genotype.

The physical indices of the seed are generally influenced by the characteristics of the hybrid and by the climatic conditions of the grain formation and filling period. Under the conditions at Secuieni, they varied according to the hybrid experienced, the values of the mass of one thousand grains being between 27.8 g (Armorik hybrid) and 33.0 g (Alimentar hybrid), and those of the hectolitric mass between 73.1 kg/hl and 76.6 kg/hl (Armorik and Foehn hybrids) (fig. 2).

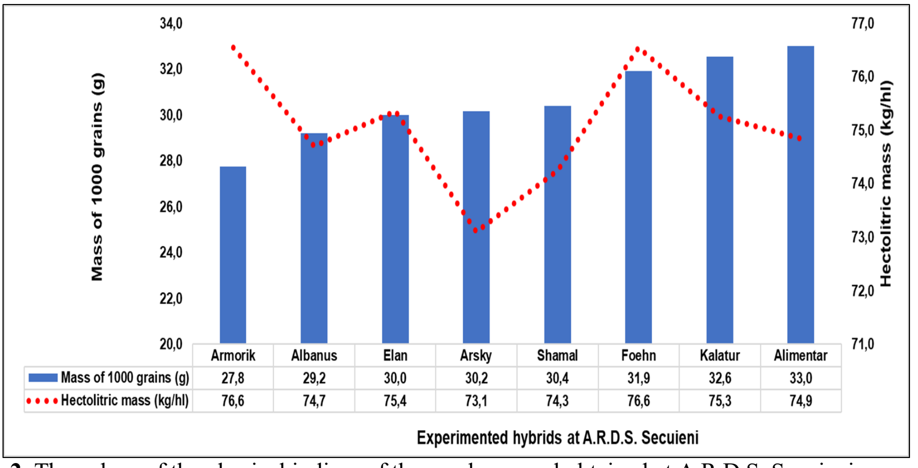


Fig. 2. The values of the physical indices of the sorghum seed obtained at A.R.D.S. Secuieni, average 2018 – 2019

Sorghum is the cereal that contains the most nutrients and, according to the latest researches, it can reduce severe asthma attacks and fights migraine. The results obtained from the analysis of the physico-chemical composition of the sorghum samples collected from the experimental field showed that the studied hybrids had a high content in starch, between 66.70 % (Foehn hybrid) and 74.66 % (Armorik hybrid) and protein total, from 8.84 % (Shamal hybrid) to 12.80 % (Elan hybrid), which makes them advantageous for use in bakery (Table 1).

Considering that the percentage of raw fiber, between 2.15 % (Arsky hybrid) and 3.95 % (Albanus hybrid), is double that of wheat flour, they take on importance in human health (Table 1).

Table 1. Physico - chemical composition of the experienced sorghum hybrids

Hybrid	Physical - chemical composition of sorghum grains (% su)				
	Proteins	Lipids	Raw fibre	Starch	Ash
Arsky	11.11	3.44	2.15	70.42	1.67
Foehn	9.64	3.90	2.69	66.70	1.60
Albanus	10.56	3.39	3.95	68.02	1.66
Shamal	8.84	3.94	2.30	67.37	1.49
Kalatur	10.57	3.82	2.64	66.94	1.61
Armorik	10.30	4.15	3.02	74.66	1.71
Elan	12.80	3.74	2.37	67.20	1.89
Alimentar	12.32	3.80	2.55	67.66	1.80

The mineral content of the sorghum samples analysed (mg/100g a.s.) had phosphorus values between 280 - 330, potassium between 520 and 610, calcium between 2.0 and 3.9, magnesium between 260 and 290, iron between 11.6 and 18.9, zinc between 1.94 and 2.42, copper between 0.23 and 0.36 and manganese between 1.60 and 1.97 (Table 2).

Table 2. Mineral content determined in sorghum hybrids experimented

Hybrid	Minerals content (mg/100 g a.s.)							
	P	K	Ca	Mg	Fe	Zn	Cu	Mn
Arsky	280	610	2.6	270	14.3	2.02	0.32	1.60
Foehn	330	530	3.9	280	18.9	2.42	0.28	1.93
Albanus	320	520	2.7	290	16.3	2.20	0.33	1.97

Shamal	280	600	3.8	260	13.6	1.94	0.23	1.70
Kalatur	290	520	2.4	270	11.6	2.07	0.35	1.82
Armorik	320	600	2.9	290	15.4	1.97	0.28	1.70
Elan	320	540	2.4	280	14.0	2.18	0.29	1.96
Alimentar	330	570	3.4	290	13.7	2.14	0.36	1.92

Comparing the results obtained (Table 2) with the daily mineral reference dose (RDI) to ensure the proper functioning of human metabolic processes (Table 3), we observe that 100 g of sorghum flour can provide more than half of the daily iron dose, the Foehn hybrid as a whole and over half the daily dose of magnesium, and the potassium content is quite satisfactory. In view of these aspects, the term "iron source" and "magnesium source" may be emitted [20, 21].

Table 3. Daily reference consumption (RDI) of macronutrients and micronutrients [22].

Mineral (maximum for sex and age groups)	Acceptable daily intake (ADI)
Calcium	1000 mg
Iron	18 mg
Magnesium	400 mg
Zinc	15 mg
Copper	2000 μg
Sodium	2400 mg
Potassium	4700 mg

The results of identifying essential amino acids in sorghum samples revealed that sorghum contains all the essential amino acids, some of which such as leucine, isoleucine, histidine and valine exceeding the recommended daily dose (FAO/ WHO/UNU). Also the sorghum seeds analyzed had an important content of methionine, threonine and phenylalanine (Table 4).

Table 4. Amino acid composition of sorghum samples collected from experimental field

	Amino Acid Composition (%)							
Amino acid	Arsky	Foehn	Albanus	Shamal	Kalatur	Armorik	Elan	Alimentar
Aspartic acid	0.60	0.55	0.56	0.48	0.59	0.57	0.60	0.50
Glutamic acid	2.12	1.95	1.84	1.63	2.01	1.93	2.08	1.80
Seryn	0.44	0.39	0.38	0.32	0.41	0.39	0.44	0.37
Glycin	0.31	0.32	0.29	0.26	0.30	0.29	0.34	0.28
Histidine	0.20	0.20	0.18	0.17	0.20	0.19	0.22	0.17
Arginine	0.36	0.36	0.35	0.30	0.36	0.34	0.38	0.33
Threonine	0.31	0.29	0.26	0.24	0.28	0.27	0.30	0.25
Alanine	0.86	0.78	0.77	0.68	0.82	0.79	0.87	0.76
Proline	0.89	0.82	0.76	0.66	0.82	0.77	0.89	0.76
Tyrosine	0.32	0.30	0.27	0.19	0.24	0.25	0.30	0.27
Valine	0.50	0.47	0.45	0.39	0.47	0.44	0.49	0.43
Methionine	0.16	0.16	0.16	0.14	0.14	0.14	0.19	0.17
Cysteine	0.11	0.10	0.11	0.12	0.12	0.14	0.13	0.12
Isoleucine	0.37	0.34	0.34	0.29	0.36	0.34	0.39	0.33
Leucine	1.30	1.16	1.16	0.97	1.22	1.18	1.34	1.16
Phenylalanine	0.51	0.44	0.42	0.32	0.42	0.43	0.50	0.42
Lysine	0.19	0.19	0.20	0.09	0.09	0.17	0.20	0.19

4 Conclusions

Sorghum is a cereal species of world importance, considering its adaptability to unfavorable environmental conditions, which is materialized by obtaining high yields that have very high nutritional qualities and improves human health.

Although the experiments at Secuieni were carried out in extremely unfavourable climatic conditions, characterized as very dry and hot, the sorghum produced large yields, ranging from 7841 kg/ha to 9718 kg/ha. Two of the eight experimented hybrids, respectively Foehn and Shamal, were noted for producing more than 9500 kg/ha.

The physical indices of the seed were influenced by the characteristics of the hybrid, and together with the high content of starch, protein and raw fibre, they represent an advantage for the use of sorghum in the baking industry. The lipid content is twice as high as wheat flour and has beneficial effects on bakery products. All eight analysed hybrids can be labelled as excellent "iron source" and "magnesium source".

The samples analysed contain all the essential amino acids, in concentrations that, some of them, exceed the recommended daily dose: leucine, isoleucine, histidine and valine. In addition to these, sorghum has a satisfactory content of methionine, threonine and phenylalanine.

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