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# TESTING OF SOME HYBRIDS OF SWEET SORGHUM AND SORGHUM x SUDAN GRASS AT BRĂILA AGRICULTURAL RESEARCH AND DEVELOPMENT STATION

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***Abstract***

*The paper aimed to present the study with sweet sorghum varieties carried out in Great Brăila Island, Romania in the 2022-2023 agricultural year. This year was considered by the World Meteorological Organization as the driest in the history of climate records at that time. This study was carried out by S.C. Eco-Sorghum Group S.R.L. in collaboration with the Agricultural Research and Development Station of Brăila within the research contract entitled "Testing of sweet sorghum hybrids (SAȘM 1 and SAȘM 2) and the sorghum x Sudan grass hybrid (SAȘM 4)" with the aim of highlighting the potential for total biomass production, technological strains, juice and bagasse and the cultivation technology appropriate to meet the eco-environmental requirements of sweet sorghum. This study of hybrids was also carried out at 6 other agricultural locations in Romania placed in the county of Arad, Argeș, Brăila, Dăbuleni, Iași and the Republic of Moldova. Following this experiment, it can be demonstrated that sweet sorghum has high potential in terms of biomass production, and also in terms of the production of juice with high sugar content. This is very important for the energy sector, by using sweet sorghum as a sustainable and affordable alternative in a context where the long-term use of fossil fuels presents quite a lot of uncertainties. Also the food industry can use sweet sorghum with very good results in the production of sugar.*

***Key words***: *sweet sorghum, biomass production, sugar content.*

## INTRODUCTION

Sorghum is part of the cereal family, ranking fifth worldwide in terms of cultivated area, after wheat, corn, rice and barley, being cultivated on 40 million hectares (Axinte, 2006; Mocanu, 2023; Sorghum Id, 2022)

Sorghum is characterized by the fact that it can adapt better to climate change conditions, especially prolonged drought and heat and less fertile soil, thus giving it the nickname of "The camel of crops" (Bâlteanu, 2003; Mocanu, 2023; Antohe, 2007)

*Sorghum bicolor* is the main representative of the *Sorghum* genus and is increasingly used for a larger cultivation area, this being possible due to the multiple uses it has, namely, in human, animal food or for industrial purposes (Bâlteanu, 2003). According to the method of use, sorghum is divided into four groups (Roman, 2006; Sarca, 2004; Soare, 2012): grain sorghum (*Sorghum bicolor* variety *eusorghum*) for which the purpose of cultivation is represented by the production of grains used for human and animal food and for industrial processing.

*Sorghum bicolor* variety *sudanese* -fodder sorghum is characterized by the fact that it is very suitable for animal feed, the stem having the property of sprouting very well and producing green biomass in a large quantity.

*Sorghum bicolor* variety *technicum* - technical or broom sorghum is used in the production of brooms or for extracting cellulose from the stem.

High-growing sugar sorghum (*Sorghum bicolor* variety *sacchartum*) or sweet sorghum is part of the same *Sorghum bicolor* and is characterized by the fact that the panicle is not very important from a productive point of view, the stem being the most important constituent part. This is

usually 1.7-4 m high, and can even reach 6.5 m (Roman et al., 2011).
The stem contains the sweet juice rich in sugar, which can be used mainly in the production of sugar but also for other food, in energy sector or other industrial purposes. Once the juice is extracted, the resulting auxiliary material, called bagasse, can be used successfully both in animal feed and for energy or industrial purposes (Antohe, 2006). Typically, sweet sorghum presents a yield of 70-100 t/ha with a very good yield in terms of fermentable sugar extraction. Thus, from one ton of sweet sorghum, 400-500 l of juice with 14-20% sugar is obtained (Antohe, 2006).
From this syrup, 7000 l of bioethanol per hectare can be obtained. From this point of view, sweet sorghum is of particular importance in that an increase in the consumption of biofuels is expected worldwide to the detriment of conventional fossil fuels (Pochișcanu, 2016).
From an agronomic point of view, studies have demonstrated the ability of sweet sorghum to combat soil erosion and prevent land desertification by incorporating the root mass and leaves resulting from harvesting into the soil, enriching the soil with humus. Also, to combat *Fusarium* leaf disease or *Agriotes spp*. worms, it is recommended to introduce sorghum into agricultural rotations. (Antohe, 2002; Pochișcanu, 2016). From an ecological point of view, sweet sorghum is very important in that it can capture 35-50 t of $CO_2$ from the atmosphere, a higher amount compared to deciduous forests or other cultivated plants. (Antohe, 2006)

## MATERIALS AND METHODS

The experience with testing sweet sorghum hybrids for green mass, in order to obtain natural sweeteners, biochar and energy pellets, took place in 2023, within the Great Brăila Island (I.M.B.) Experimental Centre on an area of 3 hectares. This study was also carried out at 6 other agricultural locations in Romania placed in the county of Arad, Argeș, Brăila, Dăbuleni, Iași and the Republic of Moldova.

### Testing area description

The I.M.B. Experimental centre is located on the territory of the Great Brăila Island, which is developed with complex land improvement works, and which in the past represented the largest natural unit in the Lower Danube Meadow with a total area of 76,700 ha. Located within the perimeter of Brăila County, the Great Brăila Island is surrounded by the waters of the Danube - the Măcin Branch (Old Danube) to the north, east and south, the Vilciu Branch and the New Danube between km 252 and km 170 to the west.

### Climatic conditions of the area

The air temperature regime, through the monthly average values and especially through the absolute amplitude, most clearly reflects the characteristics of the temperate continental climate. The annual average air temperature in Brăila is 10.9ºC. The monthly average temperatures vary over a fairly large range, from the coldest month - January with a multiannual average of -2.1ºC, to the warmest month - July, whose multiannual value is 22.9ºC.
Precipitation regime in the Great Brăila Island liquid and solid precipitation in the area of North Bărăgan is below 500 mm, with average values ranging between 400-490 mm.
The annual variability of precipitation and the uneven distribution during the year reflect the continental character of the climate in the area (Table 1).
Wind is a climatic element with a great impact on agriculture practiced in the I.M.B., having a major influence on the hydrological regime of soils, the behaviour of crops or the quality of irrigation.

### The biological material used

- SAŞM 1-simple, interlinear, late maturing hybrid with a vegetation period of 126-132 days. This hybrid is male-sterile, does not form pollen and grains with a height of 370-420 cm and tick juicy pith stem. The carbohydrate content in juice is 13.5-16%, and in favourable years up to 22%.Cultivation technology is similar to that of silage corn cultivation with a distance of 70 cm between rows, as well as in two-row strips (18-20 cm), alternating with an interval of 90-120 cm. The optimal plant density is 105-120 thousand plants/ ha. The yield when cultivated on non-irrigated is 90-120 t/ha and 20-30 t/ha of dry matter, when irrigated is 170-190 t/ha of biomass. This hybrid was approved in 2013 and is owned by the Institute of Genetics, Physiology and Plant Protection, Moldova.

Table 1. Main climatic elements of Great Brăila Island (IMB) Experimental Centre during the period October 1, 2022 - September 30, 2023

| Climatic elements | | 2022 | | | 2023 | | | | | | | | | TOTAL AVERAGE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | X | XI | XII | I | II | III | IV | V | VI | VII | VII | IX | |
| Precipitation (mm) | Monthly average | 6 | 31 | 20 | 64 | 7 | 13 | 66 | 40 | 26 | 106 | 55 | 5 | 439 |
| | Multiyear monthly average | 30 | 33 | 36 | 28 | 27 | 26 | 35 | 48 | 62 | 46 | 39 | 32 | 442 |
| | Deviation | -24 | -2 | -16 | 36 | -20 | -13 | 31 | -8 | -36 | 60 | 16 | -27 | -3 |
| Temperature ($^0$C) | Monthly average | 13 | 8.1 | 2.9 | 4.4 | 1.4 | 7.9 | 10.4 | 16.6 | 21.6 | 24.7 | 24.7 | 20.9 | 13.1 |
| | Multiyear monthly average | 11.5 | 5.6 | 0.6 | -2.1 | -0.2 | 4.7 | 11.2 | 16.7 | 20.9 | 22.9 | 22.1 | 17.3 | 10.9 |
| | Deviation | 1.5 | 2.5 | 2.3 | 6.5 | 1.6 | 3.2 | -0.8 | -0.1 | 0.7 | 1.8 | 2.6 | 3.6 | 2.1 |

- SAŞM 2-simple interlinear hybrid, medium late maturing variety with a vegetation period of 110-115 days. The hybrid is male sterile, does not form pollen and grains with a plant height of 360-400 cm. The stem is thick rich in juicy pith. The content of carbohydrates in the juice is 14-16.5% and in favourable years reaches up to 22%. 14-16 leaves with a length of 61-79 cm are formed on the main stem. The cultivation technology is similar to that of cultivating corn for silage with a row spacing of 70 cm or in two-row strips (18-20 cm), alternating with an interval of 90-110 cm. The optimal plant density is 110-120 thousand plants/ha.

Hybrid approved in 2013 and owned by the Institute of Genetics, Physiology and Plant Protection of Moldova.

- SAŞM 4-hybrid created by crossing the male-sterile line MSL-1 as a maternal form with the pollinating line SP-4.

The height of the plant during the period of full ripening is 250-280 cm, and the size of the plant at the time of the first mowing varies within the limits of 164-219 cm, and at the second mowing 113-193 cm.

The twinning of the plant at the first mowing constitutes 4-5 stems, and at the second mowing 9-11 stems. The vegetation period from the seedling phase to the first mowing is 65-72 days, and from the first mowing to the second

- length of the internode underlying the panicle

42-59 days. The hybrid is resistant to drought and lodging. The average green mass yield is 111.6 t/ha and 19.2 t/ha dry mass. The plant mass contains 11.4-15.8% protein, 3.7-4.4 carbohydrates, 24.4-29.7% cellulose and 48.9-52.7 non-nitrogenous substances.

**Cultivation technology**

- herbicide application with the total herbicide Barbarian 360 at a dose of 4l/ha;
- fertilization with D.A.P. 20.20.0 complexes at a quantity of 200 kg/ha;
- sowing of sorghum lines on 03.05.2023;
- application of Faster 10 CE insecticide at a dose of 0.5 l/ha;
- applied Urea 200 kg/ha;
- mechanical weeding.

**Biometric observations made during the vegetation period**

- average plant height;
- root length;
- base stem diameter;
- length of the second internode from the ground;
- length of the internode underlying the panicle;
- number of leaves;
- average leaf length and width;
- length of the second internode from the ground;

**Laboratory analyses of plants:**
- sugar content in the stem;
- dry matter content of the vegetative mass;
- dry matter content of the panicle;
- analysis of the concentrated sorghum juice;
- physic-chemical characteristics of the sorghum stems.

## RESULTS AND DISCUSSIONS

Under the climatic conditions of 2023, from sowing (03.05.2023) until 28.08.2023 (at the interim report), 2513 growing degree units (G.D.U.) and 199.4 mm of precipitation were accumulated, and until 31.10.2023, when the stems could be harvested, 3698 GDU and 234 mm of precipitation were accumulated.

Field observations were carried out on 26.07.2023; 24.08.2023 and on 12.10.2023 when biometric measurements in the field and laboratory determinations were carried out, on the 3 variants of the sweet sorghum varieties, in three replications.

In the case of observations recorded on 26.07.2023, in most cases, panicles were not formed and the sugar content was below the 4% threshold.

Figure 1. Observations in the sorghum experience in the Great Braila Island (IMB) Centre

Table 2. Biometric determinations performed during the vegetation period

| Observation | 26.07.2023 | | | 24.08.2023 | | | 12.10.2023 | | |
|---|---|---|---|---|---|---|---|---|---|
| | SAȘM 1 | SAȘM 2 | SAȘM 4 | SAȘM 1 | SAȘM 2 | SAȘM 4 | SAȘM 1 | SAȘM 2 | SAȘM 4 |
| 1. Plant height | 269.7 | 230.7 | 229 | 377.3 | 355.0 | 319.3 | 375.0 | 353.0 | 319.0 |
| 2. Root length | 28.0 | 21.0 | 25.3 | 34.0 | 28.7 | 30.3 | 41.2 | 40.5 | 37.3 |
| 3. Number of leaves | 9.7 | 8.0 | 7.3 | 15.3 | 14.3 | 10.3 | 15.0 | 13.3 | 9.5 |
| 4. Leaf length | 87.0 | 84.7 | 80.3 | 95.0 | 93.7 | 86.0 | 92.5 | 91.2 | 88.3 |
| 5. Leaf width | 7.5 | 7.8 | 4.6 | 8.2 | 7.7 | 4.2 | 8.0 | 7.5 | 4.0 |
| 6. Thickness of 2internode from the ground | 2.6 | 2.2 | 1.3 | 2.2 | 1.9 | 1.3 | 2.5 | 2.2 | 2.0 |
| 7. Length of internode underlying panicle | - | - | 58.5 | 38.7 | 44.2 | 57.7 | 39.2 | 44.5 | 58.0 |
| 8. Breaking resistance | 8.2 | 8.2 | 9.3 | 7.5 | 7.3 | 9.3 | | | |
| 9. Falling resistance | 8.0 | 7.7 | 9.2 | 6.3 | 6.3 | 9.2 | 6.0 | 6.0 | 8.5 |
| 10. Aphid resistance | 9.5 | 9.2 | 9.5 | 9.5 | 9.2 | 9.0 | 9.0 | 9.0 | 9.0 |
| 11. Resistance to pathogen attack | 9.7 | 9.3 | 9.0 | 9.7 | 9.3 | 9.0 | 9.0 | 9.1 | 9.0 |
| 12. Sugar content | 3.9 | 3.9 | 2.8 | 9.1 | 9.6 | 5.1 | 16.3 | 16.4 | 6.9 |

Table 3. Results of the observations regarding green biomass and dry matter

| Observation | 24.08.2023 | | |
|---|---|---|---|
| | SAŞM 1 | SAŞM 2 | SAŞM 4 |
| 1. Plant height (cm) | 377.3 | 355.0 | 319.3 |
| 2. Green plant mass (g) (stem + leaves) | 1114.4 | 917.9 | 247.3 |
| 2. Plant dry matter (stem + leaves) (g) | 219.2 | 182.6 | 44.1 |
| 3. Green panicle mass (g) | 42.7 | 40.8 | 48.8 |
| 5. Panicle dry matter (g) | 16.4 | 15.3 | 22.7 |

For the determinations made at the end of August - beginning of September, the statistical calculation performed with the Average test highlighted the following:
The average height of the plants was 377 cm at SAŞM 1, followed in descending order by SAŞM 2 (355 cm) and SAŞM 4 (319 cm).
The green mass per plant was between the values of 1.15 kg/plant for SAŞM 1, followed in descending order by SAŞM 2 with 0.91 kg/plant and by SAŞM 4 with 0.25 kg/plant, at density of 18 plants/m² for SAŞM 1 and SAŞM 2, and 26 plants/m² for the SAŞM 4 hybrid.
The average dry matter content was higher for the SAŞM 2 hybrid (60.8%), followed in descending order by the SAŞM 1 hybrid (47.1%) and the SAŞM 4 hybrid (32.2%).

Figure 2. Separation of plant parts for biomass determination

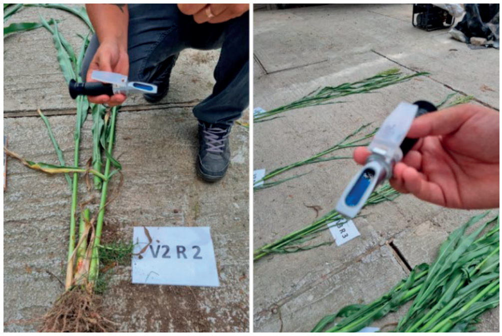


Figure 3. Determination of the sugar content in the stem by the refractometer method

The final field determinations were carried out before harvesting as green mass, respectively on October 12, 2023 and highlighted the fact that, under the pedoclimatic conditions of I.M.B., in 2023, an average of 98.6 t/ha of leafless stems from ŞAŞM 1, 86.5 t/ha of stems from ŞAŞM 2 and 24.9 t/ha of stems from ŞAŞM 4 were obtained, the sugar content determined by refractometer being 16.3% in ŞAŞM 1, 16.4% in ŞAŞM 2 and 6.9% in ŞAŞM 4 (Table 4).

Table 4. Results of the observations regarding green biomass and sugar content

| Observation | 12.10.2023 | | |
|---|---|---|---|
| | SAŞM 1 | SAŞM 2 | SAŞM 4 |
| 1. Number of plants/m² | 16.3 | 16.0 | 26.6 |
| 2. Stem weight (kg) | 9.86 | 8.65 | 2.5 |
| 3. Leaf weight (kg) | 2.06 | 1.76 | 0.8 |
| 4. Panicle weight with underlying internode (kg) | 2.19 | 2.58 | 0.9 |
| 5. Sugar content | 16.30 | 16.4 | 6.9 |

Table 5. Average biomass production obtained from the three sweet sorghum lines, tested in 8 experimental centers, under non-irrigated conditions, in 2023

| No. | Variety | Green biomass/ha | | Harvest moisture % | Density thousand plants/ha | Plant height (cm) | Yield dry matter/ha | | Stem weight (g/pl) |
|---|---|---|---|---|---|---|---|---|---|
| | | Average | Margins | | | | 40% moist. | 20% moist. | |
| 1. | SAȘM 1 | 114.1 | 82/131.9 | 71 | 156 | 310 | 64 | 32 | 730 |
| 2. | SAȘM 2 | 132.1 | 80/163 | 78 | 151 | 315 | 67 | 33.4 | 860 |
| 3. | SAȘM 4 | 34.2 | 24/45.2 | 56 | 232 | 230 | 24.3 | 12.2 | 148 |

According to Table 5, and the production results obtained in the 8 testing centers, the average amount of green biomass at harvest for the SAŞM 1 hybrid was 114.1 t/ha. The lowest amount obtained was 82 t/ha, and the highest was 131.9 t/ha. The seeding density was 156 thousand plants per hectare. The average production for the SAŞM 2 hybrid was 132.1 t/ha, with a lower production limit of 80 t/ha and an upper production limit of 163 t/ha. For the SAŞM 4 hybrid, the average biomass production was much lower compared to the first two, this is due to the fact that this last hybrid is a hybrid created in combination with Sudan grass, a hybrid used in animal feed. The production limits for this hybrid were 24 t/ha and 45.2 t/ha, respectively.

Table 6. Average yields of stalks, juice and bagasse obtained from the three lines of sweet sorghum, tested in 8 experimental centers

| No. | Variety | Stems (t/ha) | Juice (t/ha) | Bagasse (t/ha) |
|---|---|---|---|---|
| 1. | SAȘM 1 | 79.8 | 35.9 | 43.9 |
| 2. | SAȘM 2 | 88.3 | 35.2 | 52.1 |
| 3. | SAȘM 4 | 22.7 | 9.1 | 13.6 |

After harvesting the sweet sorghum, the panicle leaves and the internode underlying the panicle were removed, as they are not important in terms of the juice obtained. For the SAŞM 1 hybrid, a quantity of 79.8 stems/ha resulted. After pressing, the resulting juice was 35.9 t/ha, and the remaining material, called bagasse, was in the amount of 43.9 t/ha. For the second hybrid, SAŞM 2, the resulting quantity of stems was 88.3 t/ha. After processing, the resulting quantity was 35.2 tons of sweet juice and 52.1 t of bagasse.

For the SAŞM 4 hybrid, the quantity of stems was 22.7 tons, from which 9.1 tons of juice and 13.6 tons of bagasse resulted (Table 6).

Table 7. Concentrated sugar sorghum juice sample analyses - I.B.A. Bucharest

| No. | Determination | Unity of measure | Laboratory method | Determined value |
|---|---|---|---|---|
| 1. | Total sugar | % | Schoorl method | 61.18 |
| 2. | Reducing sugar | % | Schoorl method | 31.50 |
| 3. | Dry substance | Refract. degree | SR EN 12143:2003 | 77.38 |
| 4. | Acidity, expressed as citric acid | % | SR EN 12147:1999 0 | 1.17 |
| 5. | Polyphenols | mg/100 ml | Florin-Ciocâlteu method | 783.09 |
| 6. | Antioxidant capacity | mg/100 ml | DPPH method | 411.12 |

After obtaining the concentrated sweet juice by pressing the sweet sorghum stems, it was subjected to a set of analyses. The analyses were carried out at the National Institute for Research and Development of Food Bioresources and were as follows: total sugar content, reducing sugar, amount of dry matter, acidity, expressed in citric acid, polyphenols and antioxidant capacity. The total sugar content obtained was 61.18%, and the reducible sugar was in the amount of 31.50%. Both determinations were carried out by the Schoorl method. The dry matter obtained was 77.38 and the acidity, expressed in citric acid, was 1.17%. Both were carried out by the SR EN method. The polyphenol content was 783.09 mg/100 ml. The antioxidant capacity was 411.12 mg/ 100 ml.

Table 8. Physico-chemical characteristics of the average sorghum sample (stems)

| Parameter | % | % dry matter |
|---|---|---|
| Moisture | 72.10 | - |
| Ash | 0.94 | 3.37 |
| Total protein | 1.15 | 4.2 |
| Total fat | 0.19 | 0.68 |
| Total carbohy-drates | 25.62 | 91.83 |
| Invert sugar | 9.90 | 35.48 |
| Crude fiber | 8.51 | 30.50 |

From the analysis of the sample of sweet sorghum stems with a moisture content of 71.10%, it was observed that the total carbohydrate content was 25.62%, invert sugar 9.90, crude fiber 8.51%. The protein content was 1.15%, ash 0.94%, and fat was 0.19%.

Table 9. Testing the calorific value of sweet sorghum biomass kcal/kg

| No. | Date of sampling | Lower calorific value | Higher caloric value |
|---|---|---|---|
| 1. | 03/08/2023 | 3804 | 4097 |
| 2. | 15/09/2023 | 3912 | 4023 |
| 3. | 25/10/2023 | 4064 | 4328 |

During the vegetation period of the sweet sorghum crop, the calorific value of the biomass was also determined. This was carried out in August, September and October, close to the harvest of the crop. The analyses were carried out at the National Research and Development Institute for Industrial Ecology form Bucharest. According to the data found in Table 9, as the sorghum ripening period approached, its caloric value increased. Thus, at the third determination, the lower caloric value was 4064 kcal/kg, and the upper caloric value was 4219 kcal/kg. Values up to 3850 kcal/kg represent the capacity for use for feed purposes, and values higher than this threshold signify the capacity for use for energy purposes.

## CONCLUSIONS

The testing of the three sweet sorghum hybrids (ŞAŞM 1, ŞAŞM 2 and ŞAŞM 4), in 2023, under the pedoclimatic conditions of Great Brăila Island (I.M.B.), highlighted an important production potential in terms of biomass and sugar content, this under non-irrigated conditions.

The highest biomass production (stems) belongs to the SAŞM 1 hybrid, which recorded 98.6 t/ha, followed by SAŞM 2, with 86.5 t/ha and the SAŞM 4 hybrid presented the production of 24.9 t of fresh biomass.

In terms of sugar content, the hybrids stand out with a content of 16.4% (SAŞM 2), 16.3%-SAŞM 1 and the SAŞM 4 hybrid with 6.9%, this being, however, a hybrid intended for animal feed. According to analyses of the concentrated sorghum juice sample that were performed at I.B.A. Bucharest the total sugar content was 61.18 % which represents an important value.

It can be stated that the juice obtained from sweet sorghum stems represents an important source in the production of food sugar, and the resulting bagasse can be successfully used for both energy and feed purposes.

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the cultivation technology appropriate to meet the eco-environmental requirements of sweet sorghum. The study was performed in other 7 locations as well.

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