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STUDIES ON THE IMPLICATIONS OF THE HARVESTING PHASE, IN REALIZATION OF THE PRODUCTION COMPONENTS FOR SWEET SORGHUM

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Abstract: The objective of the study, carried out in the period 2018-2020, aimed at the influence of the harvest season on the components involved in the production of biomass obtained from sweet sorghum grown in sandy soils in southern Oltenia. The obtained results showed a maximum of the total biomass production of 80.62 t / ha, obtained when harvesting the sweet sorghum in the milk wax grain phase. Among the components of the total biomass production, the highest percentage was represented by the stems, respectively 71.2-80.5 %, depending on the harvest season. The percentage of sugar, extracted from the stem, was positively correlated with the dry matter and negatively with the leaf surface index, which recorded the maximum value (19.2%) by harvesting the sugar sorghum in the physiological maturity phase of the grain.
Keywords: biomass, dry matter, leaf index, chlorophyll, sugar

1. INTRODUCTION

Due to the high sugar content of the stems and the high proportion of starch in the grains, sorghum (Sorghum bicolor var. Saccharatum) is one of the most important agricultural sources used for biomass production, which can be processed and converted relatively easily into a type of fuel (bioethanol, synthesis gas), vegetable proteins, feed or green manure (Reddy BVS et al. 2005, Almodares A., 2008, 2009, Matei Gh, 2016, Antohe, 2007). Sweet sorghum is widely recognized as an extremely promising energy crop for biomass, with special potential to complement sugarcane production in diversified cropping systems (Kun-Jun Han et al., 2012, Tatiana Maria da Silva et al., 2017, 2018).

The quality of the sweet sorghum and the juice obtained largely depends on the time of harvest. The sweet sorghum crop, intended for obtaining the juice, must be harvested in the phase in which the highest sugar content is recorded. The literature mentions that as the plant advances to maturity, the quality of the juice improves by increasing the percentage of sucrose and decreasing the glucose (Antohe I. et al., 1991, Yuvraj Ramandeep Kaur and Harinder Singh Oberoi, 2013). Increasing the percentage of sucrose offers the possibility to extract sugar from the sweet sorghum plant, in addition to syrup.

The results obtained by Babeanu Cristina, 2017 and Matei Gh., 2016., in some sweet sorghum hybrids cultivated in southwestern Romania, show a high soluble sugar content. Total sugar varied between 14.02% and 15.87%, of which a higher percentage 67.74% to 79.43% is non-reducing sugar. Ya Li Zhao et al., 2009, in a study conducted in northern China, showed that the effects of each biotic or abiotic factor (Ex: harvest time or genotype studied), have a decisive influence on biomass, on the production of carbohydrates and ethanol. They recommend starting to harvest sweet sorghum at the early maturity of the varieties about 20 days after anthesis.

Research conducted in Kenya by Moses et al., 2017, highlights the harvest season as a determining factor in the production of bioethanol, by harvesting at intervals of 7 days after flowering, until physiological maturity. Chlorophyll, biomass, absolute ethanol volume, juice volume and sugar yield showed significant differences between genotypes and harvesting stages. The results of this study showed that the harvesting of sweet sorghum from 104 to 117 days after planting results in a high production of juice (22976 l / ha) and ethanol (1062.78 l / ha) in the EUSS 10 genotype, that there was a percentage of 16.21% sugar.

2. MATERIALS AND METHODS

The research was carried out at Research Development Station for Plant Culture on Sands Dabuleni, in the period 2018-2020 and aimed at the influence of the harvesting season on the components involved in the production of biomass for sweet sorghum, grown in sandy soils in southern Oltenia.

The experiment was placed according to the randomized block method, in 3 repetitions. Three harvest variants were studied in the BMR Gold sweet sorghum hybrid:

- V1 - flowering phase of plants
- V2 - milk wax phase of the grain
- V3 - the physiological maturity phase of the grain

The sweet sorghum crop was placed under irrigated conditions on a sandy soil with a marked chemical unevenness. Soil quality analyzes, revealed a nitrogen content between 0.035% and 0.13%, values that indicate a low state of soil supply, an extractable phosphorus content between 59 ppm and 115 ppm, values that characterize the soil as being well supplied in phosphorus and a percentage of 24 ppm and 62 ppm in exchangeable potassium, which shows a low to medium supply state. Organic carbon showed values in the range of 0.19% - 0.65%, which indicates a low state of soil supply of organic matter, and soil pH ranged between 4.83 and 6.13, values that show a strongly acidic to slightly acidic reaction. Under these conditions, the nutrient requirement of the plant was ensured by fertilization with N150P80K80.

During the vegetation period of the plant, observations and determinations were made on plant size, stem diameter, biomass production components (stems, leaves, panicles), percentage of sugar in the stem, leaf surface index, leaf chlorophyll, water and dry matter from leaves, total biomass production, using different working methods, as follows:

- The leaf area was determined using the Area Metter AM 300.
- The water and the dry matter from the leaves were determined gravimetrically, by drying in an oven at a temperature of 105 ^{o}C, for 3-4 hours.
- The chlorophyll content index (CCI units) was determined using the CCM-200 instrument.
- The sugar concentration in sorghum plants was determined with a Hand type refractometer. Refractometer has a scale 0 - 32% BRIX and temperature compensation in the range of 10-30 degrees Celsius.

The obtained results were analyzed by analysis of variance (ANOVA) and with the help of mathematical functions.

3. RESULTS

The analysis of climatic conditions, recorded during the vegetation of sweet sorghum (May-Auguat), shows the accentuation of the drought phenomenon, by increasing by 1.7 ^{0}C the air temperature compared to the multiannual average, which corroborated with the recorded rainfall, led to thermohydric stress during this period (Table 1).

The amount of 249.4 mm of precipitation, registered in the period 2018-2020, was insufficient, in relation to the requirements of the sweet sorghum plant, being necessary the application of 3-4 waterings with norms of 300 m^3 water / ha. Through the biological properties of the plant, regarding the increased resistance to drought and the reduced requirements for soil fertility, sweet sorghum is an alternative to be introduced in crop rotations on sandy soils, instead of maize (Drăghici I. et al., 2019). Sweet sorghum can thus be considered a crop of universal value, as it can be grown on all continents, in tropical, subtropical, temperate regions, as well as in poor quality soils and in semi-arid regions (G. Grassi, 2004).

The results obtained regarding the height of the plant and the diameter of the stem in sweet sorghum showed differentiations depending on the harvest season (Figure 1). Thus, the highest values regarding the height of the plant were registered when the sweet sorghum was harvested at the physiological maturity of the grain (248.20 cm), and the diameter of the stem registered the maximum in the flowering phase of the plants (20.37 mm).

Plant size has a major role in achieving biomass production in sugar sorghum (Sanyukta Shukla et. al., 2017).

The analysis of some indices of plant physiology, highlighted decreasing values of the total water content of the leaves and of the chlorophyll content, with the advancement in vegetation (Table 2).

Table 1. Climatic conditions registered at the weather station of RDSPCS Dăbuleni

Monthly climatic elements / period		April	May	June	July	August	Average / Amount May-August
Average monthly temperature (^{0}C)	2018-2020 Period	14.5	18.4	22.6	24.0	25.1	20.9
	Multiannual period (1956-2020)	11.9	17.1	21.6	23.0	22.6	19.3
	Deviation from the multiannual	2.6	1.3	1.0	0.9	2.5	+1.7
Rainfall (mm)	2018-2020 Period	37.5	59.0	70.2	50.7	32.1	249.4
	Multiannual period (1956-2020)	46.6	62.8	70.5	56.1	33.1	269.0
	Deviation from the multiannual	-9.1	-3.8	-0.3	-5.4	-1.0	-19.6

The chlorophyll content showed values between 40.3-54.3 CCI, the total water was between 67.3-74.92%, and the dry matter between 25.08-32.70%. Also, the leaf surface index was differentiated from the harvest season, registering maximum values in the flowering phase (8.69). The value of the leaf surface index, determined at the physiological maturity of the bean, decreased by 17% compared to the flowering phase, because part of the leaf apparatus went into decline.

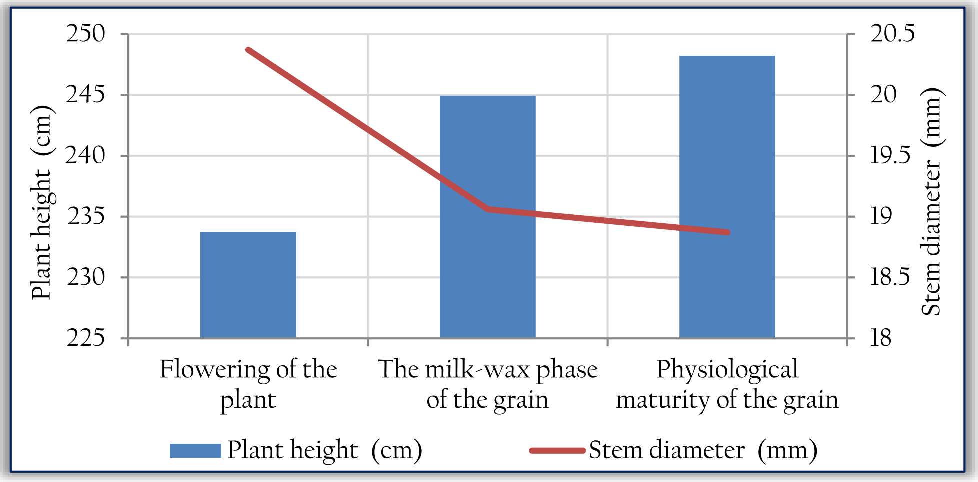

Figure 1. Results on plant growth and development, according to the time of harvest of sweet sorghum

Table 2. Physiological properties of the sweet sorghum plant harvested in different phases of vegetation

Harvest time	Dry matter (%)	Total water (%)	Chlorophyll (CCI units)	Leaf area index
Flowering of the plant	25.08	74.92	54.30	8.69
The milk-wax phase of the grain	29.33	70.67	45.50	7.75
Physiological maturity of the grain	32.70	67.30	40.30	7.21

The biomass production achieved at the sweet sorghum, in of sandy soils conditions, registered a maximum at the harvest in the milk phase of the grain wax (80.62 t / ha), with a production difference of 13.93 t / ha, insignificant compared to the harvest in the flowering phase (Figure 2). The analysis of the production on its component elements (stems, leaves, panicles), highlighted high values of the production resulting from the stems, which represented 71.2-80.5% of the total production, depending on the harvest season, followed of leaf production, with values of 14.47-17.23% and panicle production with values of 4.44-12.53% of the total biomass production.

The percentage of strains in the total biomass registered the highest value at the physiological maturity of the grain, with a percentage of 80.5%, the percentage of leaves registered the highest value at flowering (17.23%), and the percentage of panicles recorded the highest value of 12.53% in the milk-wax phenophase of the grain.

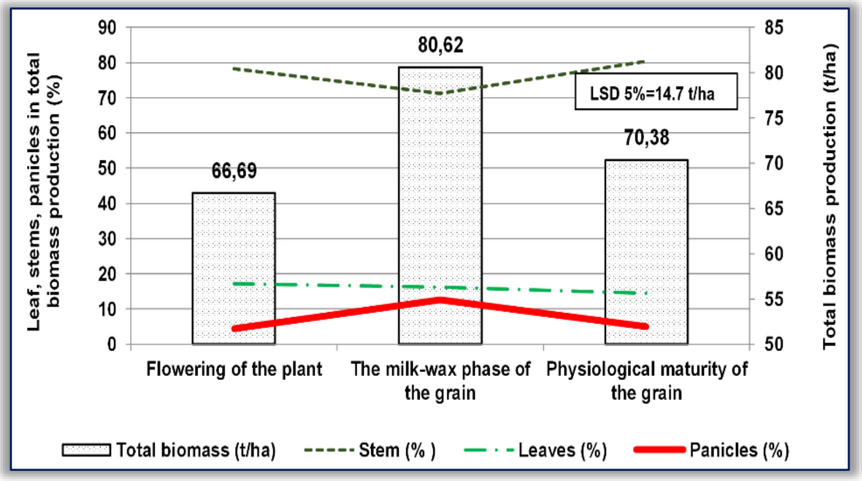

Figure 2. Total biomass production and the percentage of participation of plant components in its realization, depending on the time of harvest of sweet sorghum

Between the components of the production obtained from sweet sorghum, the leaf surface index and the dry matter from the leaves, there are distinctly significant functional links, established with the help of polynomial functions of degree II. Thus, the percentage of strains, compared to the total biomass production, was positively correlated with the dry matter and negatively with the value of the leaf surface index, because, as the plant advances in vegetation, a large part of the leaves dries (Figure 3).

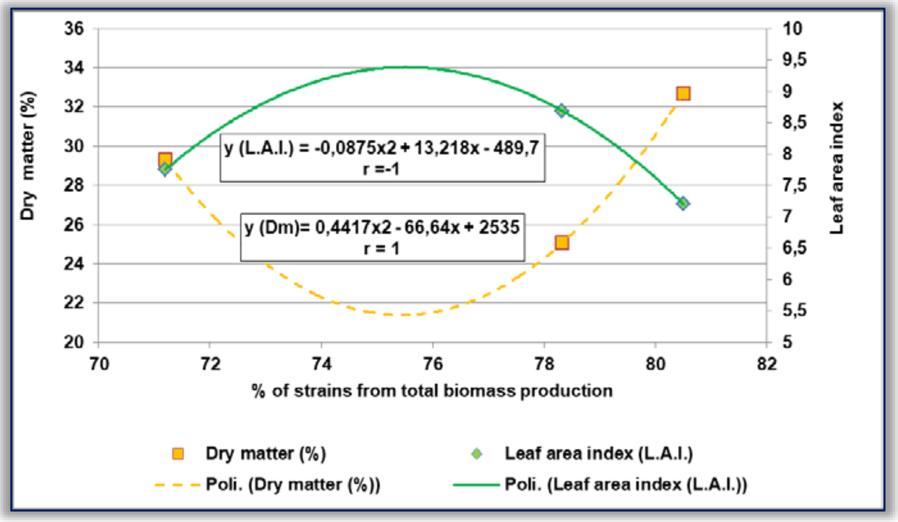

Figure 3. Correlations between the percentage of strains in the total biomass production with the dry matter and the leaf area index

Total biomass production was negatively correlated with the dry matter and positively correlated with the leaf surface index. The best balance between biomass production, leaf surface index and dry matter was achieved by harvesting the sweet sorghum in the milk-wax phase of the grain, when 80.6 t / ha of biomass were recorded, at a percentage of 29 , 33% dry matter and a leaf surface index value of 7.75 (Figure 4).

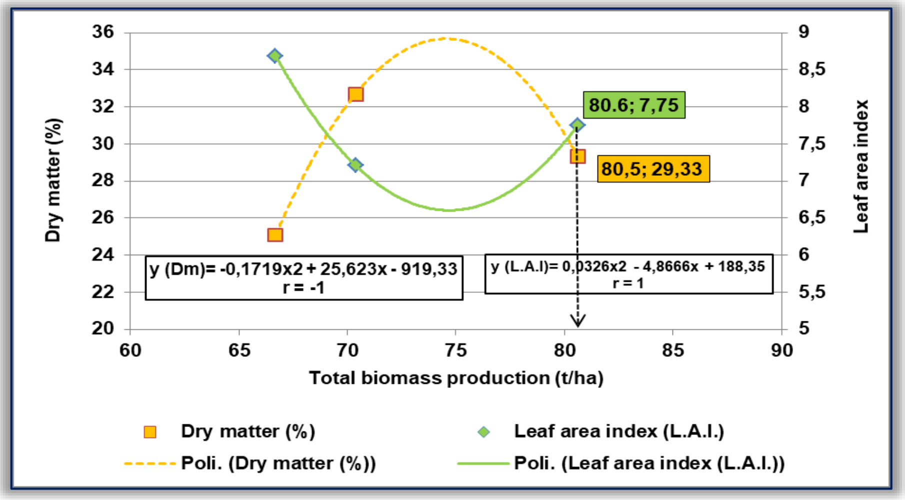

Figure 4. Correlations between total biomass production with dry matter and leaf area index recorded for sweet sorghum

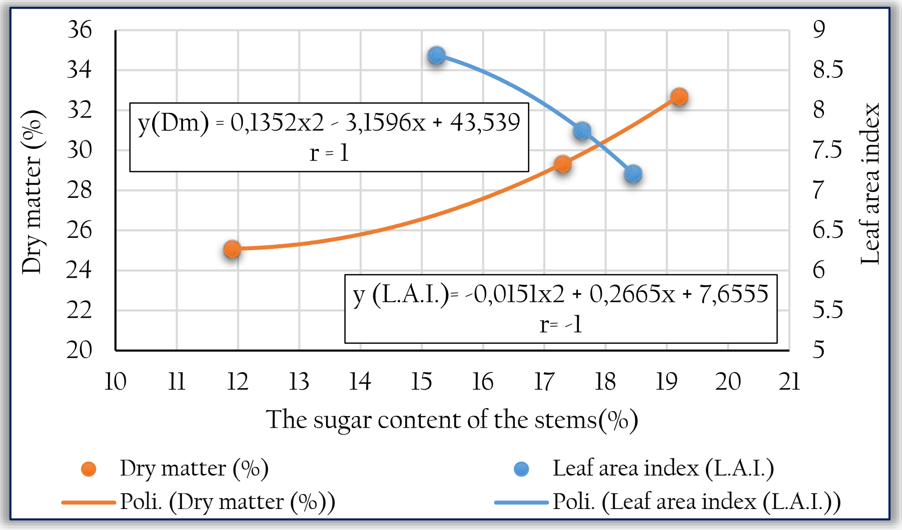

Figure 5. - Correlations between sugar content with dry matter and leaf surface index recorded for sweet sorghum

The percentage of sugar, extracted from the stem, correlated positively with the dry matter and negatively with the leaf surface index, which recorded the maximum value by harvesting the sweet sorghum in the physiological maturity phase of the grain, the phase in which the leaf surface index is minimal and the dry matter has maximum value (Figure 5). The literature mentions that as the plant advances to maturity, the quality of the juice improves, by increasing the percentage of sucrose and decreasing the percentage of glucose (Antohe I. et al., 1991).

In determining the harvest season, its destination is pursued. If we follow the biomass production, intended for animal feed, it is recommended to harvest in the milk-wax phase of the grain, and if we follow the sugar production, then the harvest is good to do in the physiological maturity phase of the grain, when the percentage of sugar in strains is maximum (19.2%), achieving 10.88 t / ha of sugar (Table 3). The results obtained in China showed that 100 liters of ethanol are produced per ton of strains, where 0.46 grams of ethanol was generated for each gram of sugar (Sanyuan Tang et al., 2018). Sweetr sorghum has a higher ethanol production potential than maize. Research published in the literature has highlighted that a crucial role in increasing the production of ethanol obtained from sorghum, is the efficiency in the use of soil, nutrients and solar radiation (Fischer-Filho et al., 2014).

Table 3. Biomass and sugar production obtained from sweet sorghum, by harvest season

Harvesting phase	Total biomass (t/ha)	Strains (% of total biomass)	Strains (t/ha)	Sugar (%)	Sugar t/ha
Flowering of the plant	66.69	78.33	52.24	11.9	6.22
The milk-wax phase of the grain	80.62	71.2	57.40	17.3	9.93
Physiological maturity of the grain	70.38	80.5	56.66	19.2	10.88

4. CONCLUSIONS

Sweet sorghum capitalizes with good results the pedoclimatic conditions in the area of sandy soils in southern Oltenia. Aweet sorghum recorded decreasing values of the total water content of the leaves (from 74.92% to 67.3%) and the chlorophyll content (from 54.3 CCI units to 40.3 CCI units), with the advancement in vegetation. Leaf area index it differed according to the harvest season, registering maximum values in the flowering phase (8.69). Biomass production, recorded a maximum at harvest in the milk phase of the wax grain (80.62 t / ha),

The analysis of the production, on its component elements (stems, leaves, panicles), revealed high values of the production resulting from the strains, which represented 71.2-80.5% of the total production, depending on the harvest season. The best balance between biomass production, leaf surface index and dry matter was achieved by harvesting sweet sorghum in the milk-wax phase of the grain, when 80.6 t / ha of biomass were recorded at a percentage of 29.33 % dry matter and a leaf surface index value of 7.75.

The percentage of sugar extracted from the stem was positively correlated with the dry matter and negatively with the leaf surface index, which recorded the maximum value by harvesting the sweet sorghum in the physiological maturity phase of the grain, the phase in which the leaf surface index is minimal and the dry matter has maximum value.

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Note:

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