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The Influence of Sowing Date and Density on Yield of Sweet Sorghum

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Abstract

Sweet sorghum is a C4 plant with a high photosynthetic efficiency that has the average of capacity to produce between 50 t/ha and 130-140 t/ha of biomass, depending on genotype, applied technology and climatic conditions. The lack or insufficiency of precipitation in many agricultural areas of the world, but also its high adaptability and capacity of sweet sorghum to generate large amounts of biomass/ha under relatively small inputs makes this crop an extremely important one for the future use: in human food, animal feed, alcohol or bioethanol, biogas or fertilizer in organic farming. Although sweet sorghum has been extensively studied by many specialists, it remains a plant that still has a lot of unknowns, especially on cultivation technology and the expression of crop of productivity capacity in various areas.

The data from the literature shows that the results obtained in the testing of technological sequences (density, distance between rows, etc.) in different climatic and soil conditions generate contradictory hypotheses. It is thus challenging to determine to what extent the nutritional space, genotype or other elements of technology influence the ability of sugar sorghum to provide large biomass production year after year. Taking in account the above mentioned features, for this purpose, within the Caracal Agricultural Research and Development Station, a research theme was initiated that aimed at optimizing technological sequences for sweet sorghum and establishing the most efficient technological measures in order to obtaining large quantities of biomass with a sugar accumulation ranging from 16 to 22% Brix. All the data obtained in the experimental field were used to generate a specific mathematical function that highlights both the participation ratio of the variables studied in the production formation and the regression indices expressed by the second degree polynomial functions related thereto.

Keywords: sweet sorghum, sowing time, density, yields

Introduction

The constant concern of scientists, regardless of their field of activity-chemistry, physics, agriculture etc. to find new sources of sustainable energy, as an alternative to fossil fuels, has brought into the light the use of this almost inexhaustible source that is biomass.

A large number developed countries (USA, China, Russia, France, Germany and other from UE, Japan, Australia etc.) had financed scientific programme in order to find new technologies, to test different species in order to find the most valuable of them, with high capacity to provide large biomass yields with very good features for processing and high level of total utility [1, 2, 3, 4, 5, 6].

Sweet sorghum proves to be one of them due the morphological, physiological and productivity characteristics such:

- High capacity of generate yields of green mass which could achieve 140-160 t/ha;
- High rate of photosynthesis with 46-56 $g/m^2/day$ [7];
- Capacity to fix through photosynthesis 50-70 mg $co_2/dm^2/h$ related the species of C3 form with 35 mg $co_2/dm^2/h$;
- Has a positive energy balance of 1.25 to 2.1 and provide high and profitable production of ethanol/ha in comparison with sugarcane, corn or sugar beet;
- The medium cost of the fermentable sugar is twice cheapest – 0.025 $/lbs – in comparison with the sugarcane – 0.045 $/lbs [5].

Methodology

The research was carried out on the Agricultural Research Development Station Caracal, during the 2015 year, using F135 ST sweet sorghum hybrid registered by INCDA Fundulea – Romania.

The soil type where we experimented was chernozem, which in this area is characterized by humus content of 3 to over 4%, which means they are moderate to strong humus, with a soil reaction of neutral to acid and the pH value range from 6 to 7. The soil is microbiologically active and well supplied with nutrients. Although have a good trophic, in order to obtain higher production it is necessary to incorporate chemical fertilizers and organic products and periodically deep loosening works.

The experiment has two factor, each one with three graduation:

A factor – sowing time (related temperature):

- a1 – 12 ºC;
- a2 – 14 ºC;
- a3 – 16 ºC.

B factor – plant's density:

- b1 – 70000 plants/ha;
- b2 – 110000 plants/ha;
- b3 – 150000 plants/ha.

The nutrients regime was ensured by 250 kg/ha of NPK product in ratio 20:20:0 which was applied before sowing and incorporated with the occasion of soil preparations. During the vegetation period we made a fertilization in 4-6 leaf of sweet sorghum stage development plants using another 80 kg/ha nitrogen active substances.

In order to ensure crop hygiene we use a treatment with Ceredin of 2 l/ha applied post emergent.

Also we applied two treatments during the vegetation with Proteus 0.4 l/ha against the pests.

The data collected in the phases of field and laboratory has been processed using statistical programs in order to generate a specific mathematical function that highlights the participation ratio of the studied factors at the total green mass obtained.

Results and discussions

Climatic conditions (Fig. 1) – during the experiment, the climatic conditions had an important influence on the evolution of sweet sorghum crop, especially that *from the point of view of precipitation* in comparison with the multiannual average which registered large deviations from the normal regime in the beginning of plant vegetation (at sowing time – end of April, first decade of May –) with differences of over 35 mm less. That fact produced a small difficulty for seeds to emerge simultaneous and create unevenness on the plants in the third epoch of sowing time.

Despite this situation, the sweet sorghum plant's had a very good capacity to recover slow stage development at the beginning of vegetation due the reason of the feature of the root system with a large number of secondary roots on primary ones and the high number of absorbent pearls, twice numerous than those from corn [8, 9].

Temperature affects not only the emergency, but also the rhythm of growth, the rhythm of leaves apparition and also the entire period of vegetation. The interaction thru the thermal factor and period of different stages in plants development is more than important into obtained high levels of yields. On the Romanian territory the quantity of temperature is different from the North part (∑T>0 of 2800 ºC) to South part (∑T>0 of 4300 ºC) [10].

From this point of view the daily rhythms of emergency for the area were we placed the experiment range from 0.100 to 0.125.

With an exception of temperatures registered in July and September, higher that the average, the year could be considered as normal from this point of view for the ARDS Caracal area.

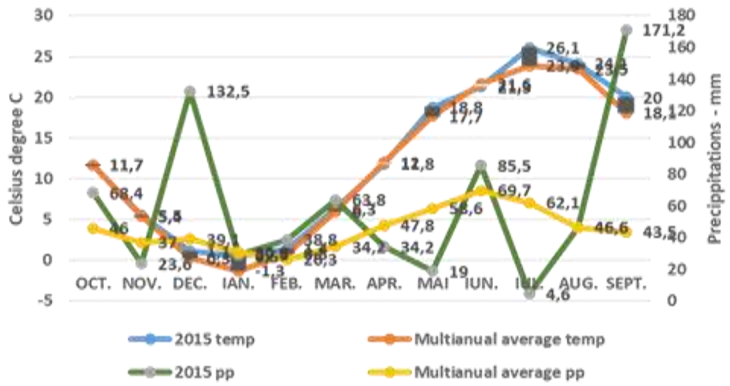

Fig. 1. Evolution of climatic conditions in comparison with multiannual average

Related to the influence of the A factor (*sowing temperature*) to the level of the total green mass yield, which is presented in the Fig. 2, it can be observe that the earlier sowing time conduct to obtain of smallest production – 69.5 t/ha – from those three variants. The highest level of level of yield has been registered when the sown was made at 14 ºC, with a total green mass production of 101.2 t/ha.

Late sowing in the conditions of ARDS Caracal is not favourable for sorghum, the level of production being closer than the best variant at 92.0 t/ha.

The increases in productions of the a2 and a3 factors were very significant from the statistical point of view and being with 45.6% and 32.3% higher than the a1 level.

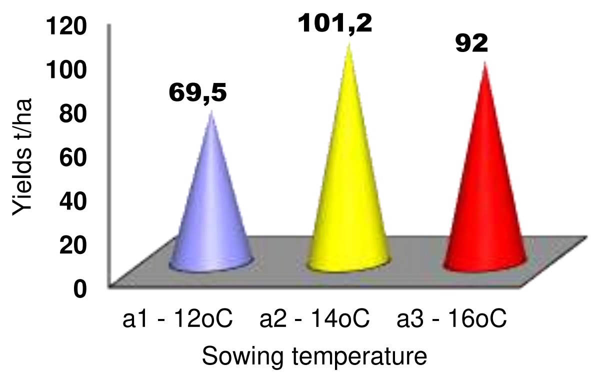

Fig. 2. The influence of the sowing time (temperature) on the total green mass yield

Although sorghum is a thermophilous plant, in the conditions of the experimented year late sown does not ensure the optimum level of water in the superficial soil layer conducting to decrease the number of plants and obviously to decrease the productions/ha.

The second factor – B – density of plant is very important in establishing the most valuable formula for sorghum crop. Not only the nutritional space of each plant is vital, but also sweet sorghum has a powerful reaction to the light in competition for this factor with other plants [11, 12].

The main registered phenomenon is the acceleration of stalk growth and earlier blooming [13]. Those reactions help plants to survive, but could have a negative influence to production capacity and finally to the total green mass production registered.

In the condition of our experiment the variants with 110000 plants/ha and 150000 plants/ha prove to be very valuable, with yields of 90.7 t/ha and respectively 106.7 t/ha, with very significant increases in production related the variant of 70000 plants/ha (Fig. 3).

The increases in production registered related the plant's density of 39.3% for b2 variant and respectively 63.9% for b3 variant, both consider as very significant in comparison with the b1 variant.

The combined influence of AxB factors – shows that there is a trend of increase production at all variants of sown simultaneous with the increase the number of plants [14, 15] (Fig. 4).

The highest values were registered on the a2 sowing time at 150000 plants/ha of 124.4 t/ha.

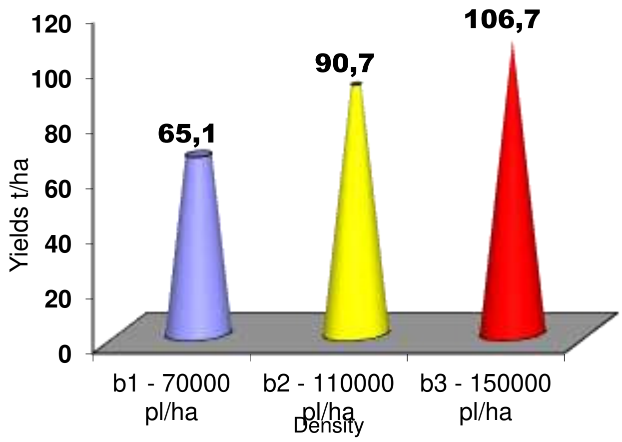

Fig. 3. The influence of density on the total green mass yield

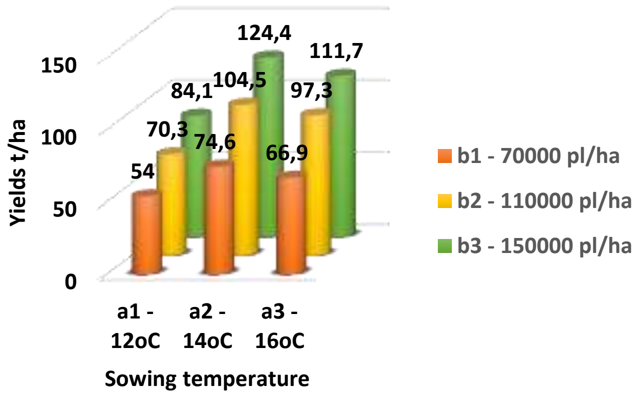

Fig. 4. The influence of combined factors AxB on the total green mass yield

Related to the statistical program used – multiple regression analysis with 2 factors: Y (related X_1 and X_2), the representative mathematical function for the analysed data has the following form:

$$Y\ (yield) = A_0 + \frac{A_1 * X_1}{(1 - X_1^2)} + \frac{A_2 * X_2}{(1 - X_2^2)}$$

The main terms of the function are:
$A_0 = 121.37$
$A_1 = 2637.15$
$A_2 = 635.41$

As results we can we can formulate the following mathematical function:

$$Y\ (yield) = 121.37 + \frac{2637.15 * X_1}{(1 - X_1^2)} + \frac{635.41 * X_2}{(1 - X_2^2)}$$

X_1 – sowing density
X_2 – sowing time (temperature in soil)
Coefficients of partial determination obtained during the processing collected data were:

- ✓ Y due X_1(density) = 0,734
- ✓ Y due X_2 (temperature) = 0,238
- ✓ Weight of the variables
  - ***sowing density = 71%***
  - ***sowing time (temperature in soil) = 29%***
- ✓ Multiple correlation coefficient = 0,913**

In the climatic conditions of the experimented year the weight of calculated variables which directly influenced the level of total green mass registered was 71% for plants density and 29% for sowing time (soil temperature).

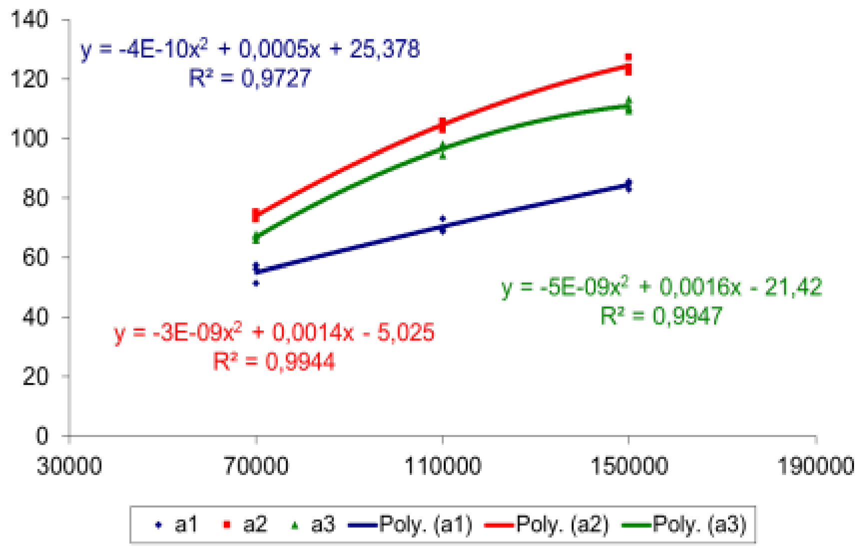

Fig. 5. Correlations between the plants density at different sown temperature and total green mass production

If we take in account the multiple correlations between total green mass production and plant's density used (Fig. 5) we can clearly highlights that the curves described by the graphical representation of the values of the productions obtained in the experimental variants reveal the superiority of the a2 – sown time at 14 ºC over the other 2 epochs: a1 – sown at 12 ºC and a3 – sown at 16 ºC. Analysing these elements resulting from the correlational correlation between the production and the studied beams, with the help of the second degree polynomial functions, we have the confirmation of the state of fact ascertained by the R^2 with values of 0.9727 to 0.9947.

Conclusions

Those two studied factors – sowing temperature and density of plants – plays a special role in growing technology of sweet sorghum. The various results mentioned in the literature shows that the climatic conditions and genotypes used have a large interaction and there is still need to research for a complete and efficient technology. The high rigidity of the sorghum, in terms of density, remains a point to be further studied and to be corroborated with elements of morphology, juice yield and sugar storage level.

In our experiment, we can highlight the capacity of the hybrid F135 ST to generate large amount of biomass, over 120 t/ha on the variant sown at 14 ºC and in the conditions of high density of 150000 plant/ha. It's also important to be mentioned the mathematical function which show us the weight of the variables to the total green mass production: sowing density with 71% and sowing time (temperature in soil) with 29%, with a very significant multiple correlation coefficient of 0,913**.

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