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STUDY REGARDING THE OPTIMIZATION OF GRAIN SORGHUM CULTIVATION TECHNOLOGY IN THE CONTEXT OF SUSTAINABLE AGRICULTURE

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Abstract

Under the current conditions of climate drying, the identification of agricultural practices with the potential to mitigate the impact of climate change on the security of agricultural production is raising more and more interest. In this context, the orientation towards drought resistant crops is emerging as an alternative solution. Known as a culture specific to areas with arid climate and poorly productive soils, grain sorghum (Sorghum bicolor (L.) Moench, var. eusorghum) has become, in the context of increasingly obvious climate change, an alternative to maize, the cultivated area of sorghum increasing annually due to the stability of the productions and their nutritional quality.
The results of the research presented in this paper show that the level of the registered productions increased with the density of plants and the increase of the nutrient doses, the productions registering values of over 8,140 kg/ha in the variant with the density of 30 seeds/square meter on the level of fertilization with $N_{150}P_{80}$ + Aminosol. The level of fertilization ensured has led to high values of production quality indices: protein and starch.

***Key words**: grain sorghum, fertilization, density, yields.*

INTRODUCTION

Worldwide sorghum culture has recorded an upward trend in last 10-15 years due his important agronomic features: resistance to drought, diseases and pests, high ecological plasticity and high and constant production.
In 2017, the world Sorghum production reached 63.9 million tons, and the average yield was of 1,427 kg/ha. The main producers of Sorghum are the USA, Nigeria, Sudan, Mexico, Ethiopia and India (Popescu et al., 2018). At EU level, sorghum represent only 0.12% from world area cultivated with sorghum and from the main EU producers of Sorghum we can highlight: Italy, France, Spain, Romania, Austria, Hungary, and Bulgaria.
The area of sorghum cultivated in Romania represent a bit of over 25% of the total EU. The data from FAOSTAT (2018 records) show that the area cultivated in Romania was 15,819 ha with an average production of 4,823 kg/ha. However, the yields obtained on grain sorghum are far below the production potential that the climatic conditions in Romania offer and that is why it is necessary as the cultivation technology to be improved.
Oprea et al., 2017, in a research carried out in South East part of Romania, using ten fertilization levels and two sowing distances between rows had concluded that both sowing distance and fertilization had a statistically significant influence on sorghum's grain yield. The most favourable combination of techno-logical factors, which ensured a maximum yield of 9.22 t/ha, was represented by sowing sorghum at the distance of 70 cm between rows and using a fertilization level N-120 P-60 K-60. Compared to the sowing distance of 50 cm between rows, the sowing distance of 70 cm between rows generated yield increases between 0.21 t/ha and 0.48 t/ha.
Pochiscanu et al., 2017, in a research from Central area of Moldavia focused on the influence of technological measures of quality of grain sorghum yield show that the sowing

density had negative influences on phenological characters and on quality of the grain, but positive on yield. The correlations were positive between fertilization with nitrogen and phosphorus and number of shoots ha^{-1}, yield and grain quality and negative between sowing density and number of shoots ha^{-1} and grain quality.

MATERIALS AND METHODS

The research was carried out at Agricultural Research and Development Station Caracal (ARDS), during the 2019 year in the conditions of a chermozem soil, medium rich in nutrient and with a humus content which varied between 3% to 4%. The soil in the arable layer (0-20 cm) has a lutearic texture with a clay content (particles below 0.002 mm) of 36.2%, an apparent density of 1.42 g/cm^3, a total porosity of 47% and one medium penetration rate (penetration resistance of 42 kg/cm^2).
From the point of view of the hydric features in the superficial layer, the wilting coefficient records the value of 12.3%, the field capacity 24.5% and the hydraulic conductivity is 9.2 mm/h.
The main aim of the research was to establish the most valuable variant of fertilization on the best density on grain sorghum. As experimented genotype we use grain sorghum hybrid Albanus (Concep III treatment) from Euralis Company, an early hybrid, with high tolerance on drought and good capacity for productions. The experiment was placed into rotation of 4 years with previous plant colza. The crop was sowing on 2th of May and the complete emergence of plants was registered 11th of May. The weed control was ensured by the treatment with Dual Gold herbicide in pre emergence and Casper herbicide applied in the first stage of plant development.
The experiment had two factors:
A factor - crop density - with three graduations:
- a1 - 20 seeds/square meter;
- a2 - 25 seeds/square meter;
- a3 - 30 seeds/square meter.

B factor - fertilization - with five graduations:
- b1 - unfertilized variant;
- b2 - $N_{75}P_{80}$;
- b3 - $N_{75}P_{80}$ + Aminosol;
- b4 - $N_{150}P_{80}$;
- b5 - $N_{150}P_{80}$ + Aminosol;

The collected data in the field were analysed using statistical ANOVA program.

RESULTS AND DISCUSSIONS

Climatic conditions (Table 1) during the experiment had an important influence on the evolution of grain sorghum crop. The recorded data certify that the 2019 year was an excessively hot year.
Compared to the normal area, an average temperature of 12.7°C was achieved, with 2.1°C higher than the normal range for the area of 10.6°C. Regarding the months of the warm period of the year (April - September) we find that in no month were temperatures lower than the multiannual average.

Table 1. Climatic conditions registered in 2019 at ARDS Caracal

2019	Temperature [°C]			Solar radiation [W/m2]	Precipitations [mm]	Wind speed [m/s]		Daily ET0
Month	**avg.**	**max**	**min**	**avg.**	**sum**	**avg.**	**max**	**[mm]**
January	-0.85	9.01	-13.47	41	38.6	1.6	8.5	0.2
February	3.42	17.41	-8.19	90	14.2	1.4	8.2	0.4
March	9.4	25.07	-3.96	156	25.2	1.7	9	2.8
April	12.11	27.16	-0.2	167	44.4	1.7	7.8	2.8
May	17.13	30.88	4.45	215	69	1.7	9.2	2.9
June	22.79	34.13	12.87	269	285.8	0.5	6	2.6
July	23.13	38.81	9.62	263	60	0.4	6.2	4.8
August	25.02	38.71	12.5	242	1	0.5	3.6	4.8
September	20.01	35.02	2.74	167	2	0.8	4.9	3.4
May-September	***21.6***	***38.81***	***2.74***		***417.8***			

The deviations were positive, ranging from 0.4ºC to 3.1ºC. It is noted as extremely hot in July, August and September, with a thermal surplus between 2.3ºC and, respectively, 3.1ºC. Also worth mentioning are the many days in July and August when the maximum temperature has exceeded the value of 38ºC and daily ETO had registered values of over 4.8 mm significantly reducing the water from soil.

During the vegetation period of the sorghum, from May to September, the total of 417.8 mm, numerically representing a sufficient value for a plant with relatively low requirements compared to the vegetation factor of water, but during the period of formation and filling of the grain, the months of August-September as very poor in precipitation, with a deficit of -49.7 mm and respectively -37.6 mm conduct to have resulted in the diminution of the elements of production, especially of the MMB.

Having a good capacity to efficiently capitalize on natural resources, sorghum has produced high yields under ecological conditions slightly favourable to other cereals (Antohe et al., 1981; Drăghici, 1989; 1999; Matei, 2011; 2016). Research has shown that the elements of technology: crop rotation and fertilization (Varvel, 2000; Khalili, 2008), crop density (Schatz et al., 1990) and distance between rows (Fernandez et al., 2012) - significantly influence the production potential of grain sorghum (*Sorghum bicolor* (L.) Moench var. *Eusorghum*).

The growth and development of the plant of grain sorghum was directly correlated with the technological factors studied: density and fertilization. The main morphological determinations made were presented in Table 2.

Table 2. The influence of fertilization and density on the development of the grain sorghum plants

A Factor Sowing density (seeds/sqm)	B Factor Fertilization (kg a.s./ha)	Height cm	Average leaves number	Panicle length cm
20	Unfertilized	106.8	8.6	23.7
	$N_{75}P_{80}$	107.3	9.0	25.4
	$N_{75}P_{80}$ + Aminosol	108.4	9.0	25.7
	$N_{150}P_{80}$	109.0	9.5	26.1
	$N_{150}P_{80}$ + Aminosol	112.0	9.8	26.3
Average		***108.7***	***9.2***	***25.4***
25	Unfertilized	106.6	8.0	25.0
	$N_{75}P_{80}$	107.3	8.5	25.2
	$N_{75}P_{80}$ + Aminosol	109.2	8.8	25.3
	$N_{150}P_{80}$	113.3	8.9	25.6
	$N_{150}P_{80}$ + Aminosol	114.6	9.4	25.6
Average		***110.2***	***8.7***	***25.3***
30	Unfertilized	115.9	7.5	25.0
	$N_{75}P_{80}$	116.5	7.6	25.6
	$N_{75}P_{80}$ + Aminosol	117.4	7.9	25.6
	$N_{150}P_{80}$	118.3	8.0	26.0
	$N_{150}P_{80}$ + Aminosol	119.0	8.0	26.3
Average		***117.4***	***7.8***	***25.7***

In the conditions of 2019, an increase in the size of the plant was observed in the range 106.6 cm to 119.0 cm, depending on the fertilization regime and in the range 108.7-117.4 cm, depending on the density of plants per unit area. Related to the leaves number we can observe that there is a positive correlation with level of fertilization - from 7.5 to 9.8 - and a negative one with plant’s density 9.2 on the smallest density to 7.8 on the highest plant’s density.

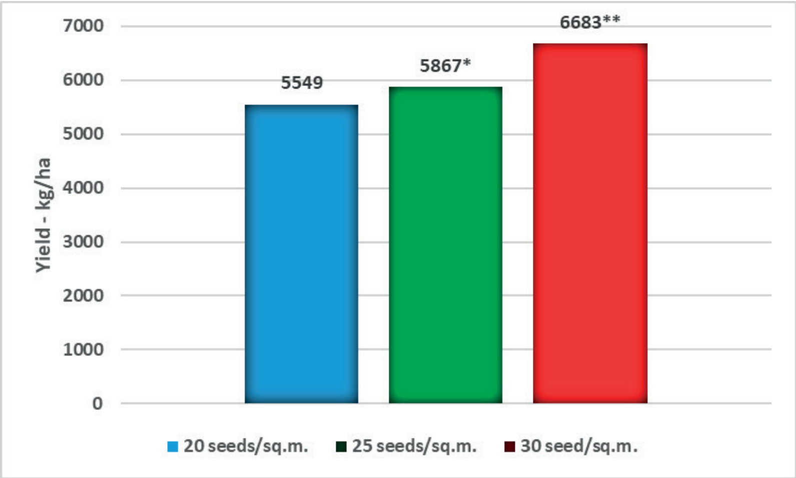
Related the panicle length, the experimented hybrid reacts only in case of fertilization, with small increase simultaneously with amount of doses and had a neutral reaction due the second factor - density - explained by very small differences between registered values.

Croitoru et al. (2018) into an experiment carried out in the condition of sandy soils from South of Oltenia, testing 10 hybrids of grain sorghum has concluded that the production potential for the area ranged between 5,077 kg/ha and 9,646 kg/ha depending of the genotype, the technology of culture and climatic conditions.

The results obtained at SCDA Caracal show that in the conditions of the year 2019 for the Caracal Plain area, sorghum is proving to be a species with real capacities of extension of the cultivated areas due to its adaptability, high production capacity and quality of grain production (Table 3, Figures 1 and 2).

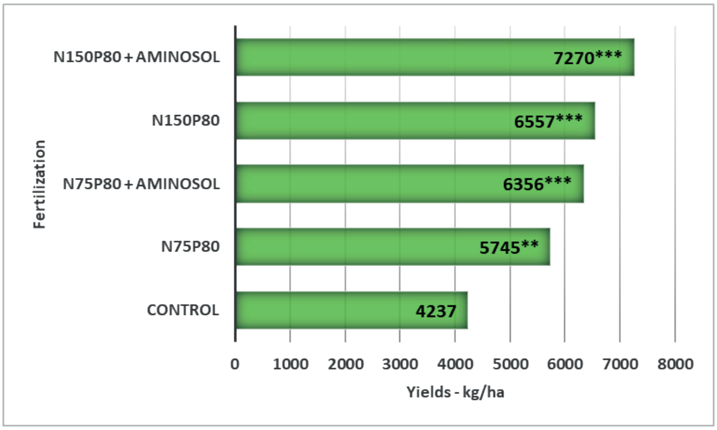
Table 3. The influence of interaction of density (A) and fertilization (B) on yield at grain sorghum

A Factor Sowing density (seeds/sqm)	B Factor Fertilization (kg a.s./ha)	Grain yields			Signification
		kg/ha	(%)	Differences kg/ha	
20	Unfertilized	3,761	62.3	-2,272	OOO
	$N_{75}P_{80}$	5,416	89.8	-617	-
	$N_{75}P_{80}$ + Aminosol	5,964	98.9	-69	-
	$N_{150}P_{80}$	6,023	99.8	-10	-
	$N_{150}P_{80}$ + Aminosol	6,583	109.1	550	-
25	Unfertilized	4,166	69.1	-1,867	OOO
	$N_{75}P_{80}$	5,511	91.3	-522	-
	$N_{75}P_{80}$ + Aminosol	6,190	102.6	157	-
	$N_{150}P_{80}$	6,386	105.8	353	-
	$N_{150}P_{80}$ + Aminosol	7,083	117.4	1,050	**
30	Unfertilized	4,785	79.3	-1,248	OO
	$N_{75}P_{80}$	6,309	104.6	276	-
	$N_{75}P_{80}$ + Aminosol	6,916	114.6	883	*
	$N_{150}P_{80}$	7,261	120.4	1,228	**
	$N_{150}P_{80}$ + Aminosol	8,142	135.0	2,109	***
Average/experience (Control)		**6,033**	**100**	**CONTROL**	**CONTROL**
LSD 5% (kg/ha)		637			
LSD 1% (kg/ha)		1,023			
LSD 0.1 % (kg/ha)		1,548			



LSD 5% - 235 kg/ha; LSD 1% - 594 kg/ha; LSD 0.1% - 1027 kg/ha

Figure 1. Influence of the A factor - plant's density - on the yields at grain sorghum



LSD 5% - 826 kg/ha; LSD 1% - 1472 kg/ha; LSD 0.1% - 2945 kg/ha.

Figure 2. Influence of the B factor - fertilization - on the yields at grain sorghum

The lowest production, of 3,761 kg/ha, was registered at the density of 20 seeds/sqm in the unfertilized version, and the highest value of the production was obtained at the density of 30 seeds/sqm in the version with $N_{150}P_{80}$ + Aminosol, of 8,142 kg/ha.

The average/experiment, used as control, has reached 6,033 kg/ha. Compared to this, it is noted on the 3 densities tested statistically assured increases in production for variants with higher levels of mineral fertilization to which was added also Aminosol, statistically assured increases at the $N_{150}P_{80}$ + Aminosol dose of 1,050 kg/ha at density of 25 seeds/sqm and 2,109 kg/ha at a density of 30 seeds/sqm. The probability of achieving a crop at a high density, of 30 seeds/sqm, is also supported by the average of the productions on the experienced densities (A factor), of 5,549 kg/ha for the density of 20 seeds/sqm, of 5,867 kg/ha for the density 25 seeds/sqm and 6,683 kg/ha at a density of 30 seeds/sqm.

The climate and soil condition of the area also allowed to obtain valuable productions also in the case of the unfertilized variants, sorghum having the capacity to capitalize on the agroproductive properties of the argic chernozem that was experimented, the average of the factor B - fertilization - ranging between 4,237 kg/ha for the unfertilized variant and 7,269 kg/ha for the $N_{150}P_{80}$ + Aminosol variant.

The role of the Aminosol ®, as biostimulator, containing 22 different amino acids and peptides (56-58%), corresponding to 9% N (110.7 g/N/l) organic nitrogen, has been highlighted in ensuring a high productivity of drought plants in drought conditions and the ability of the preparation to form a stronger root system, facilitating the absorption of nutrients from the soil and increasing the plant's resistance to drought. The applied Aminosol indirectly influenced the development of plants through the rhizosphere microbial community, which increased the absorption capacity of the nutrients in the soil and also had a very good influence to the main parameters of the quality of productions.

The quality of the grain sorghum production obtained was another goal of our research and the results of the accumulations of protein and starch (determined using a rapid seed analyser PERTEN-TA 7200) were analysed at the level of the tested variants. The recorded data shows that both factors - density and fertilization level - had influenced the chemical composition of sorghum grains, in terms of quality (Table 4). The research literature on quality of grain sorghum yields shown that Khalil et al. (1984) had obtain under the conditions of Saudi Arabia values of the protein content which varied between 15.3% and 15.9%.

Other research of related the response of grain protein concentration and yield of sorghum to nitrogen fertilization in rates of 0, 60, 120, 180, 240 and 300 kg $N.ha^{-1}$ was studied in the experimental field of Agricultural University of Plovdiv, Bulgaria in 2017-2018 under non-irrigated conditions by Kostadinova et al. (2019). The main result proved that the fertilizers and climatic conditions had a powerful influence to the quality of grain sorghum yields: rate N-300 significantly increased concentration of grain protein by 15.0% and 21.9%, respectively in 2017 and 2018, compared to N-0 plants. Fertilization N-60 - N-300 proven increased grain protein yield over the N-0. Rate N-180 provided higher grain protein yield of 708 $kg.ha^{-1}$ in 2017 and higher N-240 and N-300 rates showed a downward trend in protein yield within limits 677-708 $kg.ha^{-1}$. In snore favourable in terms of rainfall 2018, the highest grain protein yield 907 $kg.ha^{-1}$ was obtained at N-240. Application of N-300 proven reduced by 80 $kg.ha^{-1}$ the protein yield, compared to N-240 Rates 0-300 kg $N.ha^{-1}$ highly positively correlated with grain protein concentration (0.864**-0.962**) and protein yield (0.839**-0.874**) of sorghum.

Table 4. The influence of interaction of density (A) and fertilization (B) on quality of yield at grain sorghum

A Factor Sowing density (seeds/sqm)	B Factor Fertilization (kg a.s./ha)	Protein			Starch		
		%	Differences	Signification	%	Differences	Signification
20	Unfertilized	9.29	-0.37	OO	64.50	0.78	*
	$N_{75}P_{80}$	9.95	0.29	**	63.80	0.08	
	$N_{75}P_{80}$ + Aminosol	10.06	0.40	**	63.90	0.18	
	$N_{150}P_{80}$	10.09	0.43	**	63.00	-0.72	O
	$N_{150}P_{80}$ + Aminosol	10.60	0.94	***	63.50	-0.22	
25	Unfertilized	9.20	-0.46	OO	64.70	0.98	**
	$N_{75}P_{80}$	9.45	-0.21	O	63.80	0.08	
	$N_{75}P_{80}$ + Aminosol	9.51	-0.15	O	63.60	-0.12	
	$N_{150}P_{80}$	9.67	0.01		63.20	-0.52	
	$N_{150}P_{80}$ + Aminosol	10.12	0.46	**	63.40	-0.32	
30	Unfertilized	8.27	-1.39	OOO	64.60	0.88	*
	$N_{75}P_{80}$	9.36	-0.30	OO	62.90	-0.82	O
	$N_{75}P_{80}$ + Aminosol	9.7	0.04		63.10	-0.62	O
	$N_{150}P_{80}$	9.8	0.14	*	62.90	-0.82	O
	$N_{150}P_{80}$ + Aminosol	9.85	0.19	*	64.90	1.18	**
Average/experience (Control)		**9.66**	**CONTROL**	**CONTROL**	**63.72**	**CONTROL**	**CONTROL**
DL 5%		0.12			0.59		
DL 1%		0.26			0.93		
DL 0.1 %		0.71			2.04		

The protein level accumulated by the Albanus hybrid ranged from 10.60% at the $N_{150}P_{80}$ + Aminosol variant at the density of 20 seeds/sqm and 8.27% at the unfertilized variant at the maximum tested density of 30 seeds/sqm. High doses of nitrogen applied alone or in combination with the Aminosol biostimulator led to qualitative increases in production, quantified in increases in the protein level in grains, statistically assured increases predominantly at the densities of 20 and 25 seeds/sqm.

Research by Kaufman et al. (2013) showed that the protein content in sorghum grains increased with increasing nitrogen rate. Looking at the results that we present we can see the same evolutions of the protein content, starting to lowest level on the unfertilized variant and increasing to the highest level of the fertilizers on all three densities tested, from 20 seeds/sqm. to 30 seeds/sqm.

Regarding the level of starch accumulated under the conditions of experimentation in 2019, we notice the small differences between the variants, the level of the registered values falling between 62.90% for the variants $N_{75}P_{80}$ and respectively $N_{150}P_{80}$ from the density of 30 seeds/sqm and 64.70% at unfertilized variant from the density of 20 seeds/sqm. If we look at the quality data, we can notice a kind of an inverse proportional relationship between the two components: protein and starch.

CONCLUSIONS

Taking in account all the date presented in this paper, we can highlight, the follow important conclusions:

- climatic conditions of 2019 year from ARDS Caracal ensure the grain sorghum to give good productions which varied between 3,761 kg/ha obtained at unfertilized variant on the smallest density to 8,142 kg/ha registered on highest density at maximum level of applied fertilizers;
- both tested factors, sowing density and nutritional regime had very powerful influence on the level of yields, ensuring very significant increase in productions related the Control used;
- for grain sorghum cultivated on argic chernozem, the best variant of plant's density prove to be 30 seeds/square meter, variant where the average production registered was over 6,683 kg/ha;
- the level of fertilization had also a very strong influence to the yields, grain sorghum having the ability to harness very well the nutrients applied and from this point of view, the most valuable variant proved to be $N_{150}P_{80}$ + Aminosol, whatever the density tested;
- the increases in production of the variants treated with Aminosol in comparison with those without treatment, at the same level of fertilizers, shown us that the grain sorghum has a very good capacity to use the minerals applied and conduct to the development of plants through the rhizosphere microbial community, which increased the absorption capacity of the nutrients from soil;
- in terms of quality of productions, we can observe that there is a correlation between protein content and starch content, in sense that on the variant where we observe the highest content of protein, the starch level decrease - on the same density variant;
- a large nutritional space on 20 seeds/square meter conduct to a higher accumulation of protein, of 10.60% at the highest level of fertilizers of $N_{150}P_{80}$ + Aminosol.

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