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Influence of fertilization and sowing density on grain production of *Sorghum bicolor* L., in the climatic conditions of Central Moldavia, Romania

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**Abstract.** Specialists in the USA, European Union, Japan, Australia, China, etc., investigating industrial exploitation of biomass used in all forms and all adequate technologies. In this context appeared "stars biomass", of which emerges, first, to the temperate continental sorghum, known and used for many years in the USA, China, Italy and France. Improvement of some technological sequences cultivation of sorghum, is a matter of great importance to our country, in order to obtain high yields, to provide the necessary food, feed raw material in the production of bioethanol, considered a fuel of the future. Experiences has been located in the specific climatic conditions of Secuieni, Central Moldavia, bifactorial type. The biological matherial used were hybrids F32, Armida, Alize, Quebec and KSH2G06. Mineral fertilizers applied to grain sorghum crop, increased grain production. Vation in grain production in grain sorghum varies depending on hybrid and the influence of fertilization. Using higher seeding densities cause significant production increases in grain sorghum, and the production level depends of cultivated hybrid and climatic conditions. The results of this study are part of a doctoral program, funded by the Ministry of Education Youth and Sports research, the IOSUD USAMV Iași.

**Keywords:** grain sorghum, grain production, fertilization, hybrids, sowing density

**Introduction**

The climatic evolution towards heating and aridization for the 2001 – 2050 period of time in the Balkan area, where Romania is also found, compels to a reconsideration of the sorghum as: alimentary cereal (beads used in the formula for composite flours destined for gluteic and agluteic panification, the sweet juice extracted from the body, used for making syrup, vinegar and other alimentary products), fodder plant (under the shape of green mass, hay, silo), technical plant (stationary and textile celluloses, plastic material), the industry of construction materials and the handicraft industry (brushes of domestic and industrial use, brooms, nettings).

Specialists of USA, European Union, Japan, Australia, China, etc., seeking solutions for industrial exploitation of biomass used in all forms and all adequate technologies. In this context appeared "stars biomass", of which emerges, first, to the temperate-continental sorghum, known and used for many years in the USA, China, Italy and France.

Water recovery varies from one culture to another, being influenced by climatic conditions (Gumeza et al., 1989; Gumeza and Kleps, 2005; Halvorsen and Johnson, 2009) and technology elements: crop rotation, variety or hybrid, density, tillage, fertilization, weed, disease and pest control, water supply level (Domuța, 2009; Borza, 2006).

Increasing the quantity and quality of production at the current requirements is not possible without the use of fertilizers (Băleanu, 1998; Mihaila et al., 1996; Săulescu, 1967) and sowing density, expressed as the number of g.s. /m², are important because of its positive correlation with the number of plants present in the chain forming plant density at harvest (Ladek and Walkowski, 2000).

The objective of this experiment was to investigate the effect of nitrogen and phosphorus fertilization (four doses) and sowing density (four densities) to five hybrids on grain production of sorghum grain.

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**Material and methods**

The research was conducted at the Agricultural Research Development Station (ARD) Secuieni, Central Moldavia, Romania, on a typical cambic chernozem soil type, water pH 8.29, 2.3 humus content, nitrogen index 2.1, mobile P O 39 ppm, mobile K O 161 ppm after-plots method in three repetitions.

In the first experiment we tested the influence of four doses of fertilizers with nitrogen and phosphorus (unfertilized, fertilized with nitrogen (N) and phosphorus (P) with the following doses: N₅₀P₅₀; N₁₀₀P₅₀ and N₁₅₀P₅₀) on the production of five hybrids of grain sorghum (Fundulea 32, Armida, Alize, Quebec and KSH 2G06) and in the second experiment we tested the influence of four sowing densities (150.000 grains germinable/ha (g.s./ha), 200.000 g.s./ha, 250.000 g.s./ha and 300.000 g.s./ha) on the production of five hybrids of grain sorghum (Fundulea 32, Armida, Alize, Quebec and KSH, 2006).

To describe the degree of linear association between the production obtained and the doses of fertilizers, experimental densities, we calculated the Pearson correlation coefficient (r). In the experiment we have complied all the technological links, plant precursory was soybean and the data were processed and interpreted statistically by variance analysis method (Ceapoiu, 1968).

Climatic conditions in ARDS Secuieni during the experiment were close to the annual average, but the distribution of rainfall and temperatures during the sorghum growing season was uneven.

**Results and discussion**

*Influence of fertilization on grain production*

The fluctuations of the productions were large, productions are varied within very wide limits, from 2910 kg/ha to 10279 kg/ha (Table
The lowest level of production has been with the unfertilized variants. In these variants, yields ranged from 2910 kg/ha and 4185 kg/ha and were influenced by hybrids and favorable climatic conditions. The highest level of production was recorded at the fertilized variants with N\textsubscript{46}P\textsubscript{83} (120 kg/ha nitrogen and phosphorus) dose, variation in yields is between 7043 kg/ha (KSH 2G06) at 10279 kg/ha (Armida) (Table 1). From a statistical point of view, under the fertilizer applied and yields of grain sorghum hybrids obtained very strong direct correlation were recorded, the correlation coefficients interaction very significant production increases occurred, the were statistically very significant (Figure 1). This thing explains the biggest difference in production (6582 kg/ha) was obtained in the high production gains obtained from applying each dose of nitrogen and phosphorus fertilizers and hybrids sown with hybrid variant Armida which an applied dose of N\textsubscript{36}P\textsubscript{83} fertilizer brought about production increases of 2 t/ha.

We observed that between doses of nitrogen and phosphorus fertilizer applied and yields of grain sorghum hybrids obtained very significant production increases very significantly and it was concluded that a dose increase of N\textsubscript{P} fertilizer brought about production increases of 2 t/ha. We can say that hybrids with high adaptability to the Center of Moldovia, Romania are Armida and Fundulea 32 (control). Factor B (fertilization) resulted in production increases very significantly and it was concluded that a dose increase of N\textsubscript{P} fertilizer brought about production increases of 2 t/ha.

Table 1. Influence of fertilization on grain production of *Sorghum bicolor* L.

<table>
<thead>
<tr>
<th>Factor A (Hybrid)</th>
<th>Factor B (Fertilization)</th>
<th>Yield, kg/ha</th>
<th>Difference, kg</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>a\textsubscript{0} (Fundulea 32)</td>
<td>b\textsubscript{0} - N\textsubscript{P}</td>
<td>4165</td>
<td>Control</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{1} - N\textsubscript{46}P\textsubscript{83}</td>
<td>6139</td>
<td>1974</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{2} - N\textsubscript{46}P\textsubscript{83}</td>
<td>7017</td>
<td>2852</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{3} - N\textsubscript{46}P\textsubscript{83}</td>
<td>9668</td>
<td>5503</td>
<td>***</td>
</tr>
<tr>
<td>a\textsubscript{0} (Armida)</td>
<td>b\textsubscript{0} - N\textsubscript{P}</td>
<td>3697</td>
<td>Control</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{1} - N\textsubscript{46}P\textsubscript{83}</td>
<td>6039</td>
<td>2342</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{2} - N\textsubscript{46}P\textsubscript{83}</td>
<td>8705</td>
<td>5008</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{3} - N\textsubscript{46}P\textsubscript{83}</td>
<td>10279</td>
<td>6582</td>
<td>***</td>
</tr>
<tr>
<td>a\textsubscript{0} (Alize)</td>
<td>b\textsubscript{0} - N\textsubscript{P}</td>
<td>2910</td>
<td>Control</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{1} - N\textsubscript{46}P\textsubscript{83}</td>
<td>4757</td>
<td>1847</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{2} - N\textsubscript{46}P\textsubscript{83}</td>
<td>6483</td>
<td>3573</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{3} - N\textsubscript{46}P\textsubscript{83}</td>
<td>8436</td>
<td>5526</td>
<td>***</td>
</tr>
<tr>
<td>a\textsubscript{0} (Quebec)</td>
<td>b\textsubscript{0} - N\textsubscript{P}</td>
<td>3736</td>
<td>Control</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{1} - N\textsubscript{46}P\textsubscript{83}</td>
<td>6023</td>
<td>2287</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{2} - N\textsubscript{46}P\textsubscript{83}</td>
<td>7691</td>
<td>3955</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{3} - N\textsubscript{46}P\textsubscript{83}</td>
<td>8997</td>
<td>5261</td>
<td>***</td>
</tr>
<tr>
<td>a\textsubscript{0} (KSH2G06)</td>
<td>b\textsubscript{0} - N\textsubscript{P}</td>
<td>2925</td>
<td>Control</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{1} - N\textsubscript{46}P\textsubscript{83}</td>
<td>4701</td>
<td>1776</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{2} - N\textsubscript{46}P\textsubscript{83}</td>
<td>6097</td>
<td>3172</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>b\textsubscript{3} - N\textsubscript{46}P\textsubscript{83}</td>
<td>7043</td>
<td>4118</td>
<td>***</td>
</tr>
</tbody>
</table>

| Media A | a\textsubscript{0} (Fundulea 32) | 6747 | Control | - |
| a\textsubscript{0} (Armida) | 7180 | 933 | *** |
| a\textsubscript{0} (Alize) | 5647 | -601 | 000 |
| a\textsubscript{0} (Quebec) | 6612 | 364 | *** |
| a\textsubscript{0} (KSH2G06) | 5191 | -1056 | *** |

| Media B | b\textsubscript{0} - N\textsubscript{P} | 4334 | Control | - |
| b\textsubscript{1} - N\textsubscript{46}P\textsubscript{83} | 5709 | 2045 | *** |
| b\textsubscript{2} - N\textsubscript{46}P\textsubscript{83} | 7377 | 3912 | *** |
| b\textsubscript{3} - N\textsubscript{46}P\textsubscript{83} | 8448 | 5598 | *** |

Difference limit for each factor and their interaction

<table>
<thead>
<tr>
<th>DL A (kg/ha)</th>
<th>DL B (kg/ha)</th>
<th>DL BxA (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% = 147</td>
<td>5% = 84</td>
<td>5% = 188</td>
</tr>
<tr>
<td>1% = 214</td>
<td>1% = 114</td>
<td>1% = 254</td>
</tr>
<tr>
<td>0.1% = 321</td>
<td>0.1% = 151</td>
<td>0.1% = 337</td>
</tr>
</tbody>
</table>

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to 1, which shows that these hybrids really love those two macronutrients.

**Influence of sowing density on grain production**

Analyzing the influence of sowing density on the yield of sorghum, it appears that a higher density of 15 g.s./m² (grains germinable/square meter) is obtained very significant production increases and the production is influenced by the hybrids and the climatic conditions (Table 2). Density of sowing x hybrid interaction influenced the grain yield, the results are different from the five experimental hybrids and the limits are very wide – from 3293 kg/ha to 9128 kg/ha.

The yields obtained in the control variant, seeded at 150,000 g.s./ha were the lower and ranged from 3293 kg/ha (KSH 2G 06) at 5301 kg/ha (Armide), depending on the hybrids. The maximum yields of all hybrids studied were recorded at a density of 300,000 g.s./ha, their variation is quite small – from 7598 kg/ha to 9128 kg/ha. Hybrids with high adaptability to the Center of Moldova are Fundulea 32 and Armida and the factor B (seeding densities) resulted very significant increases in production and concluded that an increased density of 50,000 g.s/ha bring production increases> 1 t/ha.

The results obtained showed that between density of sowing assured and yields of grain sorghum hybrids obtained were

| Table 2. Influence of sowing density on grain production of *Sorghum bicolor* L. |
|---------------------------------|-----------------|----------------|----------------|----------------|
| Factor A (Hybrid) | Factor B (Density of sowing), g.s./m² | Yield, kg/ha | Difference, kg | Significance |
| b₁, (Fundulea 32)   | b₁ – 15          | 4887           | Control        | -             |
|                     | b₁ – 20          | 6242           | 1355           | ***           |
|                     | b₁ – 25          | 8482           | 3595           | ***           |
|                     | b₁ – 30          | 9128           | 4241           | ***           |
| b₂, (Armida)        | b₂ – 15          | 5301           | Control        | -             |
|                     | b₂ – 20          | 6070           | 799            | ***           |
|                     | b₂ – 25          | 8001           | 2670           | ***           |
|                     | b₂ – 30          | 8731           | 3430           | ***           |
| b₃, (Alize)         | b₃ – 15          | 3596           | Control        | -             |
|                     | b₃ – 20          | 5122           | 1525           | ***           |
|                     | b₃ – 25          | 6510           | 2913           | ***           |
|                     | b₃ – 30          | 7878           | 4281           | ***           |
| b₄, (Quebec)        | b₄ – 15          | 4593           | Control        | -             |
|                     | b₄ – 20          | 6126           | 1533           | ***           |
|                     | b₄ – 25          | 7550           | 2957           | ***           |
|                     | b₄ – 30          | 8904           | 4311           | ***           |

Figure 1. Graphic of correlations established between production obtained at *Sorghum bicolor* L. and doses of fertilizers
recorded very strong direct correlation, the correlation coefficients were statistically distinct significant. This thing explains the high production gains obtained from applying each density of sowing (Figure 2).

Grain yields obtained were influenced by hybrid studied, as well as the fertilizer rates and densities tested, ranging variation in grain yields 2910 kg / ha (KSH 2G06 - unfertilized) and 10279 kg/ha (Armida - \(N\), \(P\_\text{control}\)).

The interaction hybrid x fertilizer, the highest level of production was recorded in variants fertilized with \(N\), \(P\_\text{control}\) dose in yields is between 7043 kg/ha (KSH 2G06) to 10279 kg/ha (Armida).

The interaction genotype x sowing densities, the highest level of production was recorded at 300.000 variants sown g.s./ha, yields ranged between 3293 kg/ha (KSH 2G06-150000 g.s./ha) to 9128 kg/ha (Fundulea 32-300.000 g.s./ha).

**Conclusion**

Grain yields obtained were influenced by hybrid studied, as well as the fertilizer rates and densities tested, ranging variation in grain yields 2910 kg / ha (KSH 2G06 - unfertilized) and 10279 kg/ha (Armida - \(N\), \(P\_\text{control}\)).

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The interaction genotype x sowing densities, the highest level of production was recorded at 300.000 variants sown g.s./ha, yields ranged between 3293 kg/ha (KSH 2G06-150000 g.s./ha) to 9128 kg/ha (Fundulea 32-300.000 g.s./ha).

**Figure 2.** Graphic of correlations established between production obtained of *Sorghum bicolor* L. and the density of sowing.
density of sowing are direct and very significant and distinct significant.

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References

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Conclusion: The most important consequences for the science and practice resulting from the conducted research should be summarized in a few sentences. The conclusions shouldn’t be numbered and no new paragraphs be used. Contributions are the core of conclusions.

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In the text, references should be cited as follows: single author: Sandberg (2002); two authors: Andersson and Georges (2004); more than two authors: Andersson et al. (2003). When several references are cited simultaneously, they should be ranked by chronological order e.g.: (Sandberg, 2002; Andersson et al., 2003; Andersson and Georges, 2004). References are arranged alphabetically by the name of the first author. If an author is cited more than once, first his individual publications are given ranked by year, then come publications with one co-author, two co-authors, etc. The names of authors, article and journal titles in the Cyrillic or alphabet different from Latin, should be transliterated into Latin and article titles should be translated into English. The original language of articles and books translated into English is indicated in parenthesis after the bibliographic reference (Bulgarian = Bg, Russian = Ru, Serbian = Sr, if in the Cyrillic, Mongolian = Mo, Greek = Gr, Georgian = Geor., Japanese = Ja, Chinese = Ch, Arabic = Ar, etc.).

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Animal welfare

Studies performed on experimental animals should be carried out according to internationally recognized guidelines for animal welfare. That should be clearly described in the respective section “Material and methods”.