

AGRO-BIOLOGICAL RESPONSE OF GRAIN SORGHUM TO FOLIAR MINERAL FERTILIZATION AND BIOSTIMULANT APPLICATION

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Abstract

Grain sorghum (Sorghum bicolor L.) is a cereal crop of significant importance in agriculture, valued for its adaptability to diverse pedoclimatic conditions and drought resistance, and is used both for forage and human consumption. The experiment was conducted at the Agricultural Research and Development Station Secuieni, Romania (26°5' E; 46°5' N), during 2022-2024, aiming to evaluate the effect of foliar application of three products, Basfoliar 36 Extra, Terra Sorb, and Aminisol®, on the Albanus hybrid. The results highlighted a positive agro-biological response of the hybrid to foliar treatments, reflected in improved plant growth and development, as well as higher grain yield compared to the untreated control. The study emphasizes the importance of efficient use of foliar fertilizers and biostimulants in optimizing plant nutrition, contributing to increased yield and improved quality of grain sorghum.

Key words: biostimulants, drought, foliar fertilizers, sorghum, yield.

INTRODUCTION

The most widely distributed phytotechnical group worldwide, including in Romania, is represented by cereals (Roman et al., 2011). Among these, sorghum has gained increasing importance in recent years. This crop is particularly valuable in arid and semi-arid regions, where it serves as a viable alternative to maize cultivation. Sorghum's significance lies in its strong tolerance to high summer temperatures and its ability to produce high yields even under water stress conditions. Although sorghum has relatively high nutrient requirements, it does not always respond positively to the application of chemical or organic fertilizers. This behavior is attributed to its highly efficient root system, which enables effective nutrient uptake directly from the soil (Maranville et al., 1980).

Sorghum is grown in tropical, semitropical, arid and semi-arid areas, in over 120 countries across Africa, Asia, Australia and Europe (Balole and Legwaila, 2006; Shewale and Pandit, 2011; Matei et al., 2022), between the North latitudes of 50° (North America and Russia) and South

latitudes of 40° S in Argentina (Smith and Frederiksen, 2000).

This climate negatively affects the yield of agricultural crops, and agricultural research must find solutions to diversify the assortment of crops that in tougher environmental conditions guarantee the stability and profitability of agriculture. One of the safest solutions is the cultivation of sorghum, whether for grain or biomass, which due to good drought resistance, the ability to withstand high temperatures and capitalize on poorly fertile land is superior by the yields of all crops and especially, cereals and fodder plants (Isticioaia et al., 2020).

Sorghum (*Sorghum bicolor* L. Moench.) is an important crop for food and feed in several regions of the globe, being the fifth most important cereal in the world in terms of volume of yield after wheat, rice, corn, and barley (FAOSTAT, 2020). The popularity of sorghum occurs due to its drought resistance (Batista et al., 2019; Reddy, 2019; Isticioaia et al., 2020; Abreha et al., 2021), high yield potential (Clarke et al., 2019; Thomas et al., 2019), and various industrial applications.

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 yields and their nutritional quality (Matei et al., 2020).

MATERIALS AND METHODS

The experience was conducted between 2022 and 2024 at the Agricultural Research and Development Station Secuieni (A.R.D.S. Secuieni), on a typical cambic faeoziom (chernozem) soil with medium texture.

The soil is well supplied in phosphorus (77.6 ppm PAL), calcium (13.6 meq/100·g⁻¹ soil Ca), magnesium (1.8 meq/100·g⁻¹ soil Mg), medium supplied in nitrogen (16.2 ppm N-NO₃) and active humus (1.88%) and poorly supplied in potassium (124.6 ppm K₂O) with a slightly acidic pH (pH in H₂O - 5.98) (Naie et. al., 2024). The applied cultivation technology was adapted to the pedoclimatic conditions specific to the central Moldova region. Sowing was carried out at a density of 200,000 viable seeds per hectare, with a row spacing of 70 cm, and the preceding crop was sunflower. For the establishment of the experiment, a reduced agrotechnical input adapted to sorghum cultivation was used, consisting of the application of 40 kg active substance/ha of nitrogen (N) and phosphorus (P). The crop did not receive any additional fertilization.

The experiment was monofactorial, with the studied factor being sustainable foliar fertilization, applied exclusively using environmentally friendly products to a grain sorghum crop. The field experiment was laid out using a randomized block design with three replications, and the biological material used was the hybrid Albanus.

The data obtained were statistically analyzed using analysis of variance (Leonte & Simioniuc, 2018).

Foliar treatments were applied during the growing season. Basfoliar 36 Extra is a foliar fertilizer and it was applied at a rate of 8 l/ha at the 3-5 leaf stage. The foliar fertilizer Aminosol was applied at a total rate of 6 l/ha, split into two

applications of 3 l/ha at the 3-5 leaf stage and at the panicle initiation stage. Additionally, foliar biostimulant Terra Sorb was applied at a rate of 3 l/ha at the 3-5 leaf stage.

The analysis of temperature and precipitation trends during the grain sorghum growing period in the Secuieni area indicates a shift towards increasingly hot and dry conditions. Over the three years included in the study, the analysis of the thermal regime during the May-October period highlights variations in mean monthly air temperatures compared to the multi-annual average. In May, a slight negative deviation was recorded (0.5°C), indicating cooler than normal conditions. In contrast, during the June until October interval, increases in mean monthly temperatures were observed, ranging from 1.5°C to 2.7°C. The highest temperature increase occurred in August (2.7°C), followed by July and September (1.9°C) and October (1.8°C). These results reflect a warmer thermal regime during the main vegetative stages of grain sorghum (Figure 1).

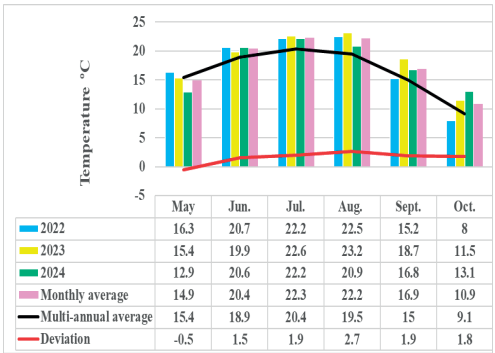


Figure 1. Temperature registered at A.R.D.S. Secuieni during grain sorghum vegetation period

The rainfall regime during the May-September period was characterized by a pronounced precipitation deficit compared to the multi-annual average. Mean monthly precipitation values showed negative deviations in all analyzed months, ranging from 11.6 mm in May to 53.1 mm in June. The most severe rainfall deficits were recorded in June, July, and August (53.1 mm, 21.7 mm, and 22.1 mm), a period corresponding to the critical growth stages of sorghum, including stem elongation, panicle formation, and grain filling. In September and October, precipitation levels remained below

the multi-annual average, with deficits of 14.4 mm and 26.4 mm, respectively (Figure 2).

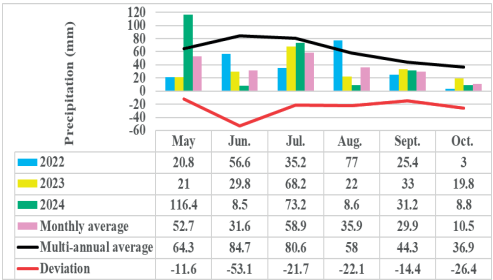


Figure 2. Precipitation registered at A.R.D.S. Secuieni during grain sorghum vegetation period

RESULTS AND DISCUSSIONS

Climatic conditions during the growing season are the primary factor influencing crop yield, particularly in regions where rainfall is the only source of water. In this context, grain sorghum represents a suitable crop due to its high tolerance to drought and high temperatures, maintaining relatively stable yields even under water limited conditions.

During the growing season, agro-biological measurements were carried out on the grain sorghum crop to assess emergence density, panicle emergence date, and plant height, in order to evaluate the effects of foliar fertilization and biostimulants.

From the emergence stage, the Albanus hybrid in the control variant (unfertilized) showed a plant density of 136,000 plants/ha, with panicle emergence observed on July 17. In the fertilized variants, emergence density ranged from 129,000 plants/ha the minimum value recorded with Aminosol application, to 142,000 plants/ha, the maximum value obtained in the variant treated with Basfoliar (8 l/ha). In all variants receiving fertilizers or biostimulants, panicle emergence was recorded on July 20, three days later than in the control variant (unfertilized).

Foliar fertilization and biostimulant applications increased grain sorghum plant height, ranging from 116.9 cm in the unfertilized to 131.4 cm in the Terra Sorb-treated variant (3 l/ha) (Table 1).

Table 1. Measurements taken during the growing season of grain sorghum, average 2022-2024

Fertilisation	Dose (l/ha)	Density at emergence (thousand plants/ha)	Heading date	Plant height (cm)
Unfertilized-Ct.	0	136	17. jul	116.9
Basfoliar	8	142	20. jul	124.5
Aminosol	6	129	20. jul	128.2
Terra Sorb	3	132	20. jul	131.4

Water and heat stress, frequently encountered in grain sorghum cultivation, especially during the early developmental stages, led to plant losses and, consequently, a reduction in crop density at harvest. However, the highest total number of harvested plants was recorded in the Basfoliar treated variant, with 238,000 plants/ha, due to a high number of tillers (128,000/ha), suggesting a significant stimulation of secondary branching. In contrast, the Terra Sorb treated variant had the highest number of main plants (117,000/ha) but a lower number of tillers (106,000/ha), resulting in a total of 223,000 plants/ha. The Aminosol treated variant showed intermediate values, totaling 217,000 plants/ha, while the unfertilized (control variant) had the lowest values, totaling 192,000 plants/ha, clearly indicating the role of foliar fertilization in stimulating tillering (Table 2). Regarding the average number of tillers per plant, these ranged from 0.78 tillers/plant in the control variant to 1.16 shoots/plant in the variant where Basfoliar was applied.

Table 2. Number of harvested plants depending on the applied fertilization under the pedoclimatic conditions at S.C.D.A. Secuieni, average 2022-2024

Fertilisation	Dose (l/ha)	Thousand harvested plants/ha			Number of tillers per plant
		Main plants	Tillers	Total plants	
Unfertilized-Ct.	0	108	84	192	0.78
Basfoliar	8	110	128	238	1.16
Aminosol	6	105	112	217	1.07
Terra Sorb	3	117	106	223	0.91

Analyzing the thousand grain weight (TGW) and hectoliter weight (HW), it was observed that foliar fertilization and biostimulants influenced the seed quality of sorghum. In the unfertilized variant, the TGW was 29.79 grams, representing the lowest value recorded. The application of Basfoliar (8 l/ha) increased the TGW to 32.21 grams, the highest value obtained in the experiment.

Regarding the hectoliter weight, values ranged from 72.9 kg/hl in the Basfoliar, treated variant to 74.2 kg/hl in the Aminosol (6 l/ha) variant (Table 3).

Table 3. Values of grain sorghum physical indices depending on the applied fertilization, average 2022-2024

Fertilisation	Dose (l/ha)	TGW (g.)	HW (kg/hl)
Unfertilized-Ct.	0	29.79	73.2
Basfoliar	8	32.21	72.9
Aminosol	6	31.25	74.2
Terra Sorb	3	30.45	73.6

Over the three years of experimentation, the Albanos variety, in the unfertilized variant, achieved an average yield of 6,256 kg·ha⁻¹, while the maximum yield of 7,780 kg·ha⁻¹ was recorded in the Aminosol treated variant. Relative yields ranged from 10% to 24% in the fertilized variants, with the highest values observed in the Aminosol treatment, followed by Basfoliar, compared to the control. The Basfoliar treatment resulted in a yield of 7,545 kg·ha⁻¹, representing an increase of 1,289 kg·ha⁻¹ and a relative yield of 21%, compared to the control variant. The highest increase compared to the unfertilized was obtained with Aminosol (7,780 kg·ha⁻¹), corresponding to a gain of 1,524 kg·ha⁻¹. In the Terra Sorb variant, the yield was 6,891 kg·ha⁻¹, which was statistically highly significant compared to the control, but lower than the yields obtained with Basfoliar and Aminosol (Table 4).

Table 4. Results on the effect of fertilization on grain sorghum yield under the pedoclimatic conditions at A.R.D.S. Secuieni, average 2022-2024

Fertilization	Yield kg·ha ⁻¹	Relative yield (%)	Dif.	Sem.
Unfertilizat-Ct.	6,256	100	-	
Basfoliar	7,545	121	1,289	***
Aminosol®	7,780	124	1,524	***
Terra Sorb	6,891	110	635	***
LSD	5%	220		
	1%	299		
	0.1%	402		

Data analysis revealed the existence of a direct correlation between the level of sorghum yield obtained under the influence of fertilizer application and the protein content of the harvest. The values of the correlation

coefficients indicate a strong relationship between the two variables, this relationship being confirmed as statistically significant and classified as highly significant ($r = 0.99^{***}$) (Figure 3).

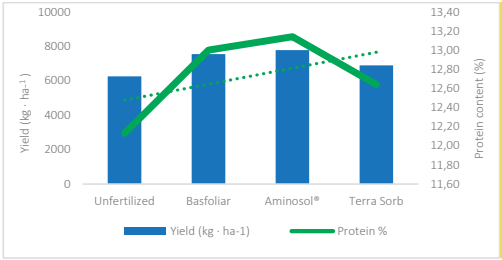


Figure 3. Correlation between grain sorghum yield (kg·ha⁻¹) and protein content (%), average 2022-2024

The application of biostimulators in sorghum cultivation led to a significant increase in grain yield, accompanied by changes in the chemical composition of the seeds. Correlation analysis revealed a negative relationship between sorghum yield and starch content ($r = -0.98^{000}$) (Figure 4), suggesting that stimulation of physiological processes by biostimulators directed the plant's metabolism toward protein synthesis and vegetative growth, at the expense of starch accumulation. This observation is supported by Zhang et al. (2023), who reported that carbon and nitrogen metabolism share common resources, and enhanced protein synthesis results in a relative decrease in starch content in the grains. The results suggest that foliar fertilization and biostimulation not only increase yield but also influence the allocation of assimilates, favoring the accumulation of structural and protein compounds, with direct effects on seed quality.

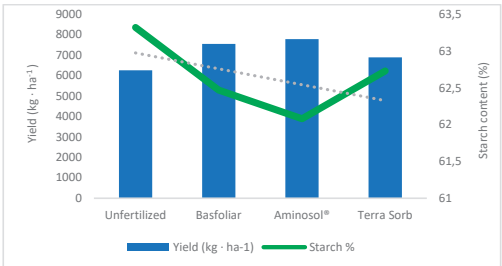


Figure 4. Correlation between grain sorghum yield (kg·ha⁻¹) and starch content (%), average 2022-2024

CONCLUSIONS

The Albanos hybrid in the control (unfertilized) treatment showed an initial density of 136,000 plants per hectare and reached panicle emergence on 17 July. In contrast, all foliar-fertilized treatments delayed this phenological stage by approximately three days, emphasizing the effect of foliar fertilization on sorghum development.

Foliar fertilizer application significantly increased plant height in grain sorghum, from 116.9 cm in the control to 131.4 cm in the treatment receiving Terra Sorb (3 L/ha), confirming the growth-promoting effect of biostimulants on vegetative development.

Grain yield was strongly influenced by foliar fertilization. The highest yields were obtained in the treatments with Aminosol (7,780 kg·ha⁻¹) and Basfoliar (7,545 kg·ha⁻¹), representing yield increases of 24% and 21%, respectively, compared with the control. These differences were statistically highly significant.

Statistical analysis also indicated a highly significant positive correlation between grain yield and protein content, suggesting that foliar fertilization enhances not only production levels but also the nutritional quality of sorghum grain.

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