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THE INFLUENCE OF SOIL TILLAGE AND FERTILIZATION ON SOME QUALITY PARAMETERS OF GRAIN SORGHUM PRODUCTION UNDER THE CLIATIC CONDITIONS OF THE SĂRĂŢENI- IALOMIŢA

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Abstract

Sorghum is a drought-tolerant crop that thrives in arid environments, which has earned it a reputation worldwide for its ability to grow in areas with limited rainfall, low soil fertility, and harsh conditions. Pedoclimatic conditions, along with the implementation of proper cultivation technologies, can increase thousand kernel weight (TKW) and protein content, ensuring better crop valorization. This research presents the results of a three-year study (2020-2023) aiming to identify the best interactions between different primary tillage practices and fertilization strategies based on nitrogen, phosphorus, and foliar fertilizers. The goal was to determine the optimal approach for non-irrigated sorghum crops in the Sărățeni region (Ialomița County) to enhance both protein content and TKW. Regarding TKW, most fertilized variants showed significantly higher values than the unfertilized control, with an increase of +6.4 g observed in the $N_{100}P_{50}$ + Borocal 1.5 L/ha (foliar) treatment. Nitrogen fertilization at 100 kg/ha significantly increased protein content to 9.3%, with a minimum gain of +0.8%. Soil tillage by subsoiling at 35 cm resulted in the highest protein content of 9.1%.

Key words: *Sorghum bicolor L., tillage, fertilization, protein, thousand kernel weight, hectoliter weight.*

INTRODUCTION

Sorghum is an adaptable and versatile cereal crop of significant importance in global agriculture (FAO). The remarkable resilience of *Sorghum bicolor* and its ability to thrive under diverse environmental conditions have earned it a reputation as a staple crop in many regions worldwide. Sorghum, a widely cultivated cereal belonging to the Poaceae family (Erbetta E., 2024), is known for its resistance and adaptability to various environmental factors, making it a key crop in many parts of the world (Abdel-Ghany S.E., 2020).

Sorghum protein is of interest due to its unique composition, which can contribute to healthy and sustainable diets. Firstly, sorghum is an important source of plant-based protein. Its protein content ranges from 8% to 14%, depending on the variety and growing conditions (Majercik et al., 2012). Compared to other cereals, sorghum has a favorable amino acid profile, being richer in essential amino acids such as lysine, which makes it an attractive option for vegetarian and vegan diets (Shabani et al., 2021). Sorghum protein is especially relevant in the context of growing interest in alternatives to animal-based proteins, aiming to reduce environmental impact (Yalçın et al., 2019). Another key aspect is the bioavailability of sorghum proteins.

Thousand kernel weight (TKW) is a significant factor in optimizing sorghum cultivation, with major implications for both yield and soil resource management. As a crop, sorghum stands out for its adaptability to diverse soil and climate conditions, including arid environments, a trait that becomes increasingly valuable under current climate change scenarios.

A study by Ailincăi et al. emphasized that proper fertilization and crop rotation management on Moldavian Plateau soils can improve both soil quality and sorghum yields. This highlights the importance of nutrient balance in enhancing agricultural productivity (Ailincăi et al., 2011). The research suggests that correct nutrient application is crucial to maximizing yield, which in turn can positively influence TKW at harvest.

MATERIALS AND METHODS

The research was conducted in the locality of Sărățeni, Ialomița County (44°38′11″N

26°55′41″E), between 2020 and 2023, on a cambic chernozem soil, within the “Bănică Ion” Individual Enterprise. The year 2021 recorded a rainfall regime above the average for the period, totaling 673.6 mm, which favored high production yields. Both during sowing and tillering stages, the amount of precipitation exceeded normal levels. During the vegetative development period (May-August) in 2021, 283.4 mm of rainfall were recorded, compared to only 96 mm in 2022 a difference of 184 mm. The year 2023 had an average rainfall regime, totaling 177 mm. The average monthly temperature during the vegetative period was 20.4°C, while the annual average for the 2020-2023 interval was 21.5°C, aligning with global warming trends.

RESULTS AND DISCUSSIONS

The Influence of Primary Tillage on Thousand Kernel Weight (TKW)

The data obtained from the experiment highlight a significant influence of primary tillage type on the thousand kernel weight (TKW) in sorghum cultivation (Table 1).

The control variant (plowing at 25 cm) recorded a TKW of 33.2 g, used as the reference value (100%). Subsoiling at 45 cm increased the kernel weight to 33.9 g, representing a gain of +0.7 g, statistically significant at the 0.1% threshold (***), suggesting improved plant development conditions under this treatment.

Table 1. The influence of primary tillage on thousand kernel weight (TKW)

Variant	TKW		Difference (g)	Significance
	g	%		
Plowing at 25 cm (control)	33.2	100	CONTROL	-
Subsoling at 45 cm	33.9	102.2	0.7	***
Subsoling at 35 cm	35.4	106.5	2.2	***
Disking at 10 cm	33.0	99.5	-0.2	
LSD 5% = 0.4 g				
LSD 1% = 0.6 g				
LSD 0.1% = 0.7 g				

The most pronounced effect was observed in the subsoiling at 35 cm variant, where TKW reached 35.4 g - a difference of +2.2 g above the control, also significant at the 0.1% level. This variant most efficiently promoted kernel formation and filling, possibly due to an optimal combination of improved soil aeration, water availability, and nutrient uptake.

On the other hand, shallow tillage through disking at 10 cm caused a slight decrease in TKW to 33.0 g, slightly below the control value, but the difference of 0.2 g was not statistically significant.

The results indicate that deeper tillage, especially subsoiling at 35 cm, positively contributes to grain mass development in sorghum, with direct implications on yield and production quality. This tillage method can be considered a valuable technological option under current pedoclimatic conditions in modern agriculture.

The Influence of Fertilization on Thousand Kernel Weight (TKW)

The control variant (N_0P_0) recorded a TKW of 31.4 g, serving as the baseline (100%). Applying nitrogen at a rate of 100 kg/ha ($N_{100}P_0$) increased kernel weight to 33.5 g, a gain of +2.1 g, statistically significant at the 0.1% threshold (***). This increase clearly indicates the effect of nitrogen on plant vigor and grain filling (Table 2).

The addition of phosphorus ($N_{100}P_{50}$) led to a TKW of 34.9 g, which is +3.5 g above the control, demonstrating the synergistic effect of the two major nutrients. This treatment had a strong positive impact on grain development, confirming the importance of nutritional balance in sorghum crop technology.

Table 2. The influence of fertilization on thousand kernel weight (TKW)

Variant	TKW		Difference (g)	Significance
	g	%		
N_0P_0	31.4	100	CONTROL	-
$N_{100}P_0$	33.5	106.7	2.1	***
$N_{100}P_{50}$	34.9	111.0	3.5	***
$N_{100}P_{50}$ + Borocal 1.5 l/ha (foliar)	37.8	120.4	6.4	***
Borocal 1.5 l/ha (foliar only)	31.9	101.4	0.5	*
LSD 5% = 0.5 g				
LSD 1% = 0.6 g				
LSD 0.1% = 0.8 g				

The highest TKW value was obtained in the $N_{100}P_{50}$ + foliar Borocal treatment, with 37.8 g -

a +6.4 g difference compared to the control, significant at the 0.1% level. This highlights the maximum efficiency of combining base fertilization with micronutrient supplementation, particularly boron and calcium, which support pericarp formation and sugar transport to the grains.

Foliar fertilization alone had a marginal effect, with a TKW of 31.9 g, a modest increase of +0.5 g, significant only at the 5% level (*). This suggests that in the absence of adequate base fertilization, foliar application alone cannot compensate for essential nutrient deficiencies.

The Influence of Tillage on Hectoliter Weight (HW)

Hectoliter weight (HW) is a key indicator of the physical and commercial quality of sorghum grains, reflecting their density and degree of filling. The results show a clear influence of soil tillage on this parameter (Table 3).

In the control variant, with plowing at 25 cm, HW was 61.8 kg/hl, used as the reference value (100%). Deeper tillage by subsoiling at 45 cm and 35 cm increased HW to 63.1 kg/hl and 63.4 kg/hl, respectively - differences of +1.4 and +1.6 kg/hl compared to the control, both statistically significant at the 0.1% level (***). These increases suggest a positive effect of deep soil loosening on the formation of dense, well-developed grains, likely through better water and nutrient supply during grain filling.

Table 3. The influence of primary tillage on hectoliter weight (HW)

Variant	HW		Difference (kg/hl)	Significance
	kg/hl	%		
Plowing at 25 cm (control)	61.8	100	CONTROL	-
Subsoling at 45 cm	63.1	102.2	1.4	***
Subsoling at 35 cm	63.4	102.6	1.6	***
Disking at 10 cm	61.0	98.8	-0.8	***
LSD 5% = 1.9 kg/hl				
LSD 1% = 2.5 kg/hl				
LSD 0.1% = 3.3 kg/hl				

In contrast, the disking variant (shallow tillage) yielded a lower HW value of 61.0 kg/hl, with a negative difference of -0.8 kg/hl compared to the control. Although the absolute value of the difference is small, it was statistically significant at the 0.1% level (***), reflecting a real negative impact on the physical quality of the grains.

These findings confirm that deep tillage, particularly subsoiling, improves the physical quality of production by increasing hectoliter weight - a key advantage for both processing and commercial valorization. In contrast, shallow tillage may limit the plant's physiological potential to produce well-filled and dense grains.

The Influence of Fertilization on Hectoliter Weight (HW)

The data presented in Table 4 reveal a significant influence of fertilization on test weight (TW) in 2021. The unfertilized control variant (N_0P_0) recorded a value of 60.1 kg/hl, serving as the baseline for comparison with the other treatments.

The application of nitrogen at a rate of 100 kg/ha without phosphorus ($N_{100}P_0$) led to an increase in test weight to 62.0 kg/hl. The 2.0 kg/hl increase was statistically significant at the 0.1% level (***). This suggests a positive effect of nitrogen even in the absence of phosphorus, likely due to the stimulation of metabolic processes involved in the formation of storage compounds.

Table 4. The influence of fertilization on hectoliter weight

Variant	HW		Difference (kg/hl)	Significance
	kg/hl	%		
N_0P_0	60.1	100	CONTROL	-
$N_{100}P_0$	62.0	103.2	2.0	***
$N_{100}P_{50}$	63.5	105.7	3.4	***
$N_{100}P_{50}$ + Borocal 1.5 l/ha (foliar)	65.1	108.3	5.0	***
Borocal 1.5 l/ha (foliar only)	60.9	101.4	0.8	
LSD 5% = 2.1 kg/hl				
LSD 1% = 2.8 kg/hl				
LSD 0.1% = 3.7 kg/hl				

The highest TW value was obtained in the $N_{100}P_{50}$ + Borocal treatment - 65.1 kg/hl. The increase of 5.0 kg/hl compared to the control exceeded the 0.1% significance threshold, confirming the effectiveness of supplementing base fertilization with a foliar Borocal treatment. This result suggests that the interaction between macronutrients and the micronutrients in Borocal plays an important role in improving crop quality parameters.

Also, the $N_{100}P_{50}$ variant (without foliar treatment) achieved an intermediate test weight value of 63.5 kg/hl significantly higher than the control (+3.4 kg/hl), but lower than the variant with Borocal highlighting the additional benefit of foliar application.
The variant treated solely with Borocal, without base fertilization, generated a test weight of 60.9 kg/hl, only 0.8 kg/hl above the control. This difference was not statistically significant, indicating that Borocal alone is insufficient to significantly improve test weight and acts effectively only in combination with adequate base fertilization.

The Influence of primary tillage on protein content

The results in Table 5 highlight the distinct effects of primary tillage type on protein content in sorghum grains under the 2021 conditions. Conventional plowing to 25 cm served as the control variant, with an average protein content of 8.8%, used as the reference point for comparison.
Soil tillage through subsoiling to 45 cm resulted in the same protein content as the control (8.8%), with no statistically significant difference. This suggests that, under the given pedoclimatic conditions, the additional tillage depth did not significantly influence nutrient availability.

Table 5. Influence of primary tillage on protein content

Variant	Protein		Difference	Significance
	Content (%)	%		
Plowing at 25 cm	8.8	100	CONTROL	-
Subsoling at 45 cm	8.8	100.2	0.0	
Subsoling at 35 cm	9.1	102.9	0.3	***
Disking at 10 cm	8.6	98.0	-0.2	ooo
LSD 5% = 0.2%				
LSD 1% = 0.2%				
LSD 0.1% = 0.3%				

In contrast, subsoiling at 35 cm led to a statistically significant increase in protein content, reaching 9.1%. The +0.3 percentage point difference compared to the control was significant at the 0.1% level (***), indicating that this working depth favored better root development and more efficient nitrogen uptake an essential nutrient for protein synthesis.
Minimum tillage, represented by disking to 10 cm, negatively affected protein content, lowering the average to 8.6%. The –0.2 percentage point difference from the control was statistically significant at the 1% level (ooo), confirming that shallow tillage limits root system development and access to nutrients in deeper soil layers.

The Effect of Fertilization on Grain Protein Content

Sorghum grain protein content responded significantly to the fertilization regime, confirming the importance of mineral nutrition especially nitrogen in stimulating plant protein metabolism.
In the unfertilized control variant (N_0P_0), protein content was 8.5%, serving as the reference value (100%). The application of nitrogen alone ($N_{100}P_0$) resulted in the highest protein content of 9.5%, an increase of +1.0% over the control - a statistically significant difference at the 0.1% level (***), confirming nitrogen's crucial role in protein biosynthesis (Table 6).

Table 6. Influence of fertilization on protein content

Variant	Protein		Difference	Significance
	Content (%)	%		
N_0P_0	8.5	100	CONTROL	-
$N_{100}P_0$	9.5	111.5	1.0	***
$N_{100}P_{50}$	9.3	108.8	0.8	***
$N_{100}P_{50}$ + Borocal 1.5 l/ha (foliar)	8.7	102.1	0.2	*
Borocal 1.5 l/ha (foliar)	8.3	97.9	-0.2	ooo
LSD 5% = 0.2 %				
LSD 1% = 0.3%				
LSD 0.1% = 0.3%				

Although the $N_{100}P_{50}$ treatment maintained a high protein value (9.3%), it showed a slight decrease compared to the nitrogen-only variant. While the difference was still statistically significant (*), the addition of phosphorus did not further enhance protein synthesis. It is possible that phosphorus had a more pronounced effect on other yield components, such as grain weight, at the expense of protein concentration.

Supplementing the $N_{100}P_{50}$ treatment with Borocal (1.5 l/ha) resulted in a decrease in protein content to 8.7%, a value close to the control but still statistically significant at the 5% level (*). This suggests a possible dilution effect, either due to increased biomass production or a specific physiological influence of Borocal's micronutrients (boron and calcium) on the carbon-to-nitrogen ratio.

The treatment with Borocal alone, without base fertilization, resulted in the lowest protein content—8.3%, a decrease of –0.2% compared to the control, statistically significant at the 0.1% level (ooo). This confirms that micronutrients, in the absence of nitrogen input, are insufficient to sustain effective protein synthesis.

The data clearly show that nitrogen is the key factor in boosting protein content. Its application, alone or in combination with phosphorus, leads to significant increases. On the other hand, foliar micronutrient applications cannot replace basic fertilization and may even reduce protein concentration under certain conditions.

CONCLUSIONS

The thousand kernel weight was significantly influenced by both soil tillage depth and the applied fertilization regime. The highest values were recorded when deep scarification was combined with complete fertilization ($N_{100}P_{50}$), emphasizing the synergistic effect of these agrotechnical practices on enhancing the physical quality of sorghum seeds. Moreover, the integrated application of nitrogen, phosphorus, and foliar treatment with Borocal resulted in the greatest hectoliter weight, suggesting a synergistic interaction that positively affected grain quality. Overall, the findings highlight a cumulative beneficial effect of soil tillage and fertilization on grain protein content. Deep tillage, particularly scarification, in conjunction with nitrogen fertilization, produced the most favorable results, underscoring the critical role of incorporating these technological factors into sorghum cultivation strategies to optimize grain quality.

Subsoling at a depth of 35 cm was the most effective in increasing grain protein content, whereas shallow tillage practices such as disking exerted a detrimental influence on this qualitative parameter.

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