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INFLUENCE OF CLIMATIC CONDITIONS, VARIETY AND SOWING DENSITY ON WHEAT PRODUCTION AND QUALITY

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Abstract

The aim of the study was to highlight the reaction of the cultivated variety depending on the sowing density and climatic conditions on the level of production and quality indices. The wheat varieties tested were Biharia, Glosa and Anapurna, on three densities (530 b.g/m^2, 650 b.g/m^2 and 780 b.g/m^2). Fertilization was carried out using N150 kg s.a., P2O5 78 kg s.a. at sowing, and in spring an additional N 46 kg s.a. was applied. The highest production was obtained for the Anapurna variety of 8403 kg/ha, followed by the Biharia variety with 7790 kg/ha and Glosa with 7587 kg/ha. Depending on the sowing density, the highest harvest, 8009 kg/ha, was obtained at a density of 780 b.g/m^2. The crude protein content ranged from 13.10% for the Glosa variety (780 b.g/m^2) to 15.9% for the Anapurna variety (650 b.g/m^2). Wet gluten recorded values between 25% for the Glosa variety (530 b.g/m^2) and 36% for the Anapurna variety (780 b.g/m^2).

Key words: *crude protein, density, gluten, variety, wheat.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important staple crops globally, providing essential nutrients to billions of people. Wheat production and quality are influenced by several key factors, including climatic conditions, variety selection, and crop density. Scientific research has extensively explored these variables to optimize wheat yield and improve grain quality.

Climatic factors, such as temperature, precipitation and solar radiation, play a key role in the growth and development of wheat. According to a study published in Nature Climate Change, an increase in global temperatures of 1°C could reduce wheat yield by 6%, highlighting the crop's sensitivity to heat stress (Asseng et al., 2015; Smuleac et al., 2020). High temperatures, especially during the cereal filling period, accelerate plant metabolism, leading to a reduction in grain size and weight (Pop et al., 2023). In contrast, adequate rainfall and optimal temperatures promote healthy wheat development (Fischer & Edmeades, 2010). Moreover, climate variability influences the prevalence of diseases. For example, warmer and wetter conditions increase the risk of fungal diseases such as rust and fusarium disease, which degrade grain quality and reduce market value (Beres et al., 2020).

Selecting the right wheat varieties is crucial for optimizing both grain yield and quality. Modern breeding programs focus on developing varieties that are drought-resistant, disease-tolerant, and able to thrive in various climatic conditions (Mosleth et al., 2015). Genetically improved wheat varieties can increase production potential by 20-30% while maintaining grain quality (Feng et al., 2018).

Grain quality parameters such as protein content, gluten strength and kernel hardness are influenced by both genetic factors and environmental interactions (Shewry & Hey, 2015; Yang et al., 2023). It is very important to select high-protein varieties for the quality of bread making, while softer wheat varieties are preferred for the pastry and confectionery industry. In addition, certain varieties are bred for biofortification, increasing the content of micronutrients such as zinc and iron to combat malnutrition (Gulyas et al., 2024).

Sowing density, or the number of seeds planted per unit area, significantly affects wheat growth, and ultimately yield (Sun et al., 2023). It is shown that the optimal seeding density varies depending on the wheat variety and environmental conditions (Hetea et al., 2024). High seeding densities can increase competition for resources, leading to thinner stems and an increased susceptibility to sheltering (fall), while low densities can lead to underutilization of available nutrients and sunlight.

However, adjusting the seeding density can optimize the yield under specific conditions. For example, in drought-prone areas, lower seeding densities reduce competition for water, improving plant hardiness (Constantin et al., 2024). In contrast, in fertile, irrigated environments, higher sowing densities maximize production potential by increasing the number of growers and grains per square meter.

The interaction between climatic conditions, variety and sowing density determines both quantitative (yield) and qualitative (grain quality) results in wheat production. For example, while higher temperatures can reduce overall yield, selecting heat-tolerant varieties and adjusting the seeding period can mitigate adverse effects. Combining hardy varieties with optimized seeding density and adequate mineral fertilization with nitrogen, phosphorus, and potassium, it can sustain wheat production in the face of climate change (Carvalho et al., 2016; Tadesse et al., 2019; Castro et al., 2022).

Grain quality, especially protein concentration, is also influenced by these factors (Blumenthal et al., 2014; Hetea et al., 2024). Recent studies note that moderate water stress during the grain filling stage can increase protein content, albeit at the expense of grain size. Similarly, seeding density affects nutrient uptake, with denser seeding reducing nitrogen availability per plant, potentially decreasing protein content (Dier et al., 2018; Ahmed et al., 2020; Chitu et al., 2024).

MATERIALS AND METHODS

The study was carried out on a vertisol soil, located in the area of Olari Commune in Câmpia Crişurilor, with a weak acid reaction and a humus content of 3.45.

The experience was three-factorial, where Factor A - the year of cultivation, Factor B - the cultivated variety (b1 - Biharia, b2 - Glosa and b3 - Anapurna), Factor C - sowing density (c1 - 780 g.s./m^2, c2 - 650 g.s./m^2 and c3 - 530 g.s./m^2).

For the climatic characterization, the data recorded at the Arad Meteorological Station were used. From the analysis of the data, it can be seen that in terms of the degree of water supply and the temperatures recorded, there were no very large deviations between the experimental years. Fertilization was carried out using N150 kg s.a., P_2O_5 78 kg s.a. at sowing, and in spring an additional N 46 kg s.a. was applied.

RESULTS AND DISCUSSIONS

Table 1 shows the wheat production (kg/ha) in two consecutive agricultural seasons (2022-2023 and 2023-2024), depending on climatic conditions. In the agricultural year 2022-2023, the production was 7877 kg/ha, and in the agricultural year 2023-2024, the production was 7841 kg/ha, the difference between the two years is -36 kg/ha, which indicates a slight decrease in production, but the variation in production is not large enough to be considered statistically significant. Since the observed difference (36 kg/ha) is well below the materiality threshold of 196 kg/ha (LSD 5%), we can conclude that the climatic variations between the two years did not have a significant impact on wheat production. It can be concluded that, under the analyzed experimental and climatic conditions, wheat production was stable between the agricultural years 2022-2023 and 2023-2024, without statistically significant differences.

Table 1. Wheat production according to climatic condition

Year	Yield kg/ha	%	Difference kg/ha	Significance
2022-2023	7877	100	-	-
2023-2024	7841	100	-36	Ns
LSD 5% = 196 kg, LSD1% = 274 kg, LSD 0.1% = 388 kg				

Wheat yields by cultivated varieties are shown in Table 2.

The wheat production achieved by the varieties was 7587 kg/ha of Biharia, 7597 kg/ha of Glosa and 8403 kg/ha (111% compared to Biharia) of Anapurna variety.

Production differences: Glosa vs. Biharia: the difference is 10 kg/ha, insignificant (ns) and Anapurna vs. Biharia: the difference is 816kg/ha, which represents an increase of 11% compared to Biharia. The difference of 816kg/ha in the case of the Anapurna variety significantly exceeds all thresholds, which confirms a very high significance (***) at a confidence level of 99.9%.

Table 2. Wheat production according to variety

Variety	Yield kg/ha	%	Difference kg/ha	Significance
Biharia	7587	100	-	-
Glosa	7597	100	10	ns
Anapurna	8403	111	816	***
LSD 5% = 221 kg, LSD 1% = 306 kg, LSD 0.1% = 421 kg				

On the other hand, the difference between Glosa and Biharia is only 10 kg/ha, well below the minimum significance threshold (LSD 5% = 221 kg/ha), so it is not statistically significant. In conclusion, the Biharia and Glosa varieties had a similar production, without statistically significant differences. The Anapurna variety recorded a significantly higher production compared to Biharia and Glosa, the difference being extremely statistically significant. This result suggests that Anapurna is a superior variety from the yield perspective under the experimental conditions analyzed.

Table 3 shows the influence of sowing density on wheat production, comparing three density levels: 530 g.s./m^2, 650 g.s./m^2 and 780 g.s./m^2.

Wheat production according to sowing density was 7683 kg/ha at 530 g.s./m^2, 7885 kg/ha at 650 g.s./m^2 and 8009 kg/ha at 780 g.s./m^2.

The optimal density for maximum production is 780 g.s./m^2, having the highest production (8009 kg/ha).

Reducing the density to 650 g.s./m^2 does not significantly affect production, which means that this density could be an economically efficient option, having almost the same production with lower seed consumption.

Reducing the density to 530 g.s./m^2 significantly reduces production, so this density is not recommended for maximum yield.

The materiality threshold confirms that the differences between 780 g.s./m^2 and 650 g.s./m^2 are insignificant, while the differences between 780 g.s./m^2 and 530 g.s./m^2 are significant at a high confidence level (99%). If the main objective is maximum production, it is recommended to use the density of 780 g.s./m^2, and if you want to streamline seed costs, without significant production losses, you can use the density of 650 g.s./m^2.

Table 3. Wheat production according to sowing density

Density	Yield kg/ha	%	Difference kg/ha	Signifi –cance
780 g.s./m^2	8009	100	-	-
650 g.s./m^2	7885	98	-124	Ns
530 g.s./m^2	7683	96	-326	**
LSD 5% = 219 kg, LSD 1% = 316 kg, LSD 0.1% = 405 kg				

The Duncan test (Table 4), is a multiple comparison method used to identify significant differences between means. Values with different letters indicate statistically significant differences.

The Anapurna variety (8403 kg/ha) is in group A, which means that it has a significantly higher production compared to the other varieties Biharia (7587 kg/ha) and Glosa (7597 kg/ha) which are in the same group B, indicating that there are no significant differences between them.

Table 4. Duncan test results for Factors B and C

Duncan Test	LSD5%	Original Data	Value	Category	Sorted Data	Sorted Value	Sorted Category
Factor B	239.7 kg	Mean 1	7587	B	Mean 3	8403	A
		Mean 2	7597	B	Mean 2	7597	B
		Mean 3	8403	A	Mean 1	7587	B
Factor C	219.3 kg	Mean 1	8009	A	Mean 1	8009	A
		Mean 2	7885	AB	Mean 2	7885	AB
		Mean 3	7683	B	Mean 3	7683	B

*Note: The data represent the mean values of different levels tested under Duncan's multiple range test, with the sorted values reflecting the highest to lowest ranking

The difference between Anapurna and the other two varieties exceeds the significance threshold (LSD 5% = 239.7kg), which confirms the superiority of the Anapurna variety.

The sowing density of 780 g.s./m^2 (8009 kg/ha) is in group A, indicating a significantly higher production compared to the density of 530 g.s./m^2. The density of 650 g.s./m^2 (7885 kg/ha) is in group AB, which suggests that there is no significant difference from the density of 780 g.s./m^2 (the difference of 124 kg is below the materiality threshold).

There is a slightly significant difference from the density of 530 g.s./m^2, but not clear enough to be completely separated into group A. The

density of 530 g.s./m^2 (7683 kg/ha) is in group B, which indicates a significantly lower production compared to the density of 780 g.s./m^2.
These results suggest that in order to achieve optimal production, the Anapurna variety and a sowing density of 650-780 g.s./m^2 are recommended, depending on costs and other available resources.
Figure 1 shows the percentage contribution of the influencing factors on wheat production: crop year (Factor A), cultivated variety (Factor B) and sowing density (Factor C), together with the percentage attributed to the experimental error.
The cultivated variety has the greatest impact on wheat production (77.71%). This result suggests that the choice of variety is decisive for achieving a high yield. Considering the previous data, the Anapurna variety had a significantly higher production, which justifies the high weight of this factor.
Climatic conditions and annual variability have a moderate contribution in influencing production (12.70%). Although climatic conditions have a visible impact, the differences between the years analysed were not statistically significant, but they still contribute to a greater extent than density.

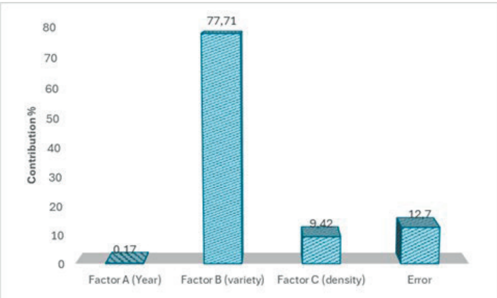

Figure 1. Contribution of factors A [crop year], B [cultivated variety], C [sowing density]

Sowing density has a relatively small impact on wheat production compared to the variety and crop year (9.42%). Although under certain conditions a higher density has led to an increase in production, this factor is not as influential as the choice of variety.
The very small percentage attributed to the error (0.17%) indicates a high precision of the experiment and a reduced variability not explained by factors. This suggests that the results are reliable and well controlled.
The cultivated variety is the most important factor, influencing production in a proportion of almost 78%. Choosing the right variety, such as Anapurna, can bring significant improvements in production.
The year of cultivation has a moderate contribution, which means that climatic variations and annual conditions play an important role, but not as decisive as the variety.
Sowing density has less impact on production, suggesting that after choosing the optimal variety, adjusting the sowing density can optimize production, but it will not have as great an effect.
In conclusion, it can be said that prioritizing the selection of the high-yielding wheat variety is essential for maximizing production. If the optimal variety is chosen, optimizing the sowing density and monitoring the climatic conditions can additionally contribute to increasing production. Given the relatively low influence of density, the additional costs associated with increasing seeding density must be weighed against the benefits.
The variation in protein content depending on the year of cultivation is shown in Figure 2.

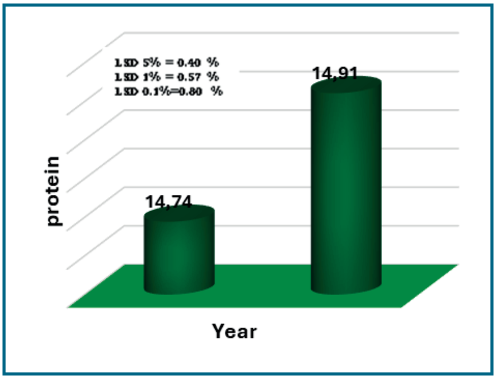

Figure 2. Variation of protein content depending on climatic conditions

The year of cultivation did not have a significant impact on the protein content in the wheat in the experiment carried out.
Although a slight increase in protein content was observed in the second year (14.91% vs. 14.74%), this difference is statistically

insignificant and can be attributed to natural variability or other factors not analyzed.
Climatic factors or other year-specific conditions did not significantly influence the protein composition, suggesting that other factors, such as the variety grown or agricultural technology, could have a greater impact on protein content.

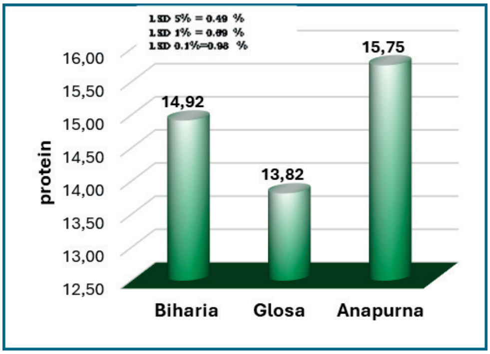

Figure 3. Variation of protein content depending on variety

The protein content (%) for the three wheat varieties, together with the values of the limits of statistical significance, is shown in Figure 3.
The Anapurna variety has the highest protein content (15.75%), being significantly higher than the other two varieties. This variety is an optimal choice if you want to obtain a higher quality of wheat in terms of protein content.
The Biharia variety has an intermediate protein content (14.92%), but still significantly higher than the Glosa variety.
The Glosa variety has the lowest protein content (13.82%), being significantly lower than the other two varieties.
Scientific interpretation of the results on the protein content (%) in wheat according to sowing density (Figure 4).
Density 3 (530 g.s./m^2) vs. Density 1 (780 g.s./m^2) is 0.69%, and this difference exceeds the significance threshold LSD 1% (0.69%), which indicates a significant difference at a 99% confidence level. A lower density (530 g.s./m^2) results in a significantly higher protein content compared to a high density (780 g.s./m^2).
Density 2 (650 g.s./m^2) vs. Density 1 (780 g.s./m^2) is 0.50%. This difference exceeds the 5% LSD materiality threshold (0.49%), making it significant at a 95% confidence level. Decreasing the density from 780 to 650 g.s./m^2 leads to a significant increase in protein content.
Density 3 (530 g.s./m^2) vs. Density 2 (650 g.s/m^2) was 0.19%, is insignificant and denotes that decreasing the density from 650 to 530 g.s/m^2 does not produce a significant increase in protein content.

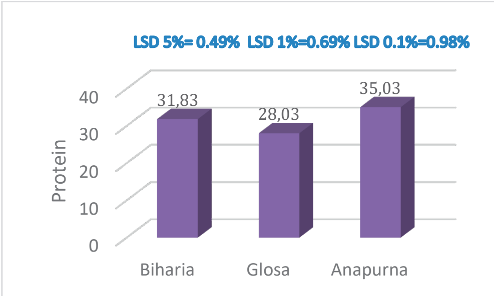

Figure 4. Variation of protein content depending on density

Lower seeding densities (530 and 650 g.s./m^2) result in a higher protein content compared to the high density of 780 g.s./m^2.
The significant difference between the high density (780 g.s. /m^2) and the other two densities suggests that too thick sowing can reduce the quality of protein in wheat.
Between 530 g.s./m^2 and 650 g.s./m^2 there are no significant differences, suggesting that a density of 650 g.s./m^2 could be optimal, providing a balance between protein content and other possible benefits such as yield.
Scientific interpretation of the results regarding the contribution of factors to the protein content in wheat (Figure 5).

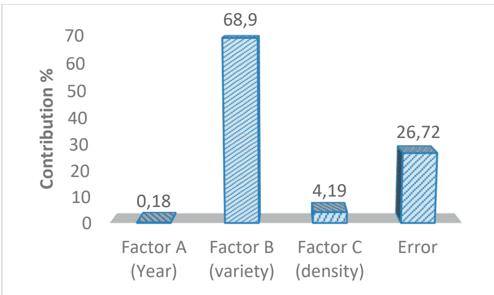

Figure 5. Contribution of factors A [crop year], B [cultivated variety], C [sowing density] to protein content

The cultivated variety (Factor B) is the most important factor influencing the protein content in wheat, contributing 76.47% to the total variation. Choosing the right variety is essential for improving the quality of wheat. Sowing density (Factor C) has a moderate impact (10.17%). Adjusting the density can bring improvements, but its effect is secondary to the choice of variety. The crop year (Factor A) has a minimal intake (0.85%), which suggests that the climatic conditions between the years analyzed had an insignificant impact on the protein content. The experimental error (12.51%) indicates that there are additional factors that may influence the protein content that were not included in this study. The choice of variety is crucial for obtaining a wheat with a high protein content Optimizing the sowing density can help to increase the quality, but it must also be analyzed according to the total yield and associated costs.

The variation of gluten content (%) in wheat according to climatic conditions in the crop year is shown in Figure 6.

The gluten content was slightly higher in the year 2022/2023 (31.78%) compared to 2023/2024 (31.49%), but this difference is not statistically significant. The climatic conditions in the two years analyzed did not significantly influence the quality of wheat in terms of gluten content.

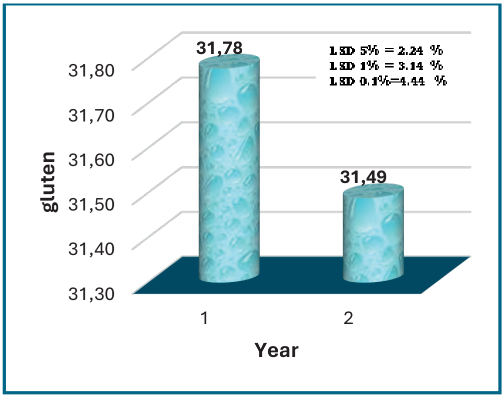

Figure 6. Variation of gluten content (%) in wheat according to climatic conditions in the crop year

The influence of the wheat variety on the gluten content (%), is shown in Figure 7.

The Anapurna variety (b3) has the highest gluten content (35.03%), being significantly higher than both varieties, Biharia and Glosa. The Biharia variety (b1) has an intermediate gluten content (31.83%), being significantly better than Glosa, but lower than Anapurna, and the Glosa variety (b2) has the lowest gluten content (28.03%), being significantly lower than the other two varieties.

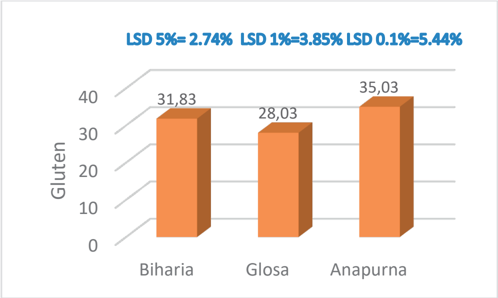

Figure 7. Variation of gluten content (%) in wheat according to variety

The variation of gluten content according to three density levels: 780 g.s./m^2 (c1), 650 g.s./m^2 (c2) and 530 g.s./m^2 (c3), is presented in Figure 8.

As the sowing density decreases, the gluten content increases. However, this increase is not statistically significant in this experiment.

The density of 530 g.s./m^2 had the highest gluten content (32.33%), but the difference from the higher densities is not significant.

The density of 780 g.s./m^2 had the lowest gluten content (30.67%), but the differences from the other densities are not large enough to be considered statistically significant.

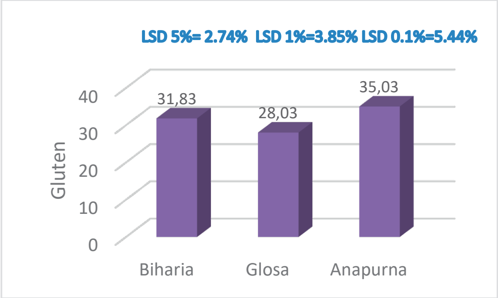

Figure 8. Variation of gluten content (%) in wheat according to density

The contribution of factors A [crop year], B [cultivated variety], C [sowing density] to the achievement of the gluten content of wheat is shown in Figure 9.

Analyzing the data obtained, it appears that the wheat variety (Factor B) has the greatest impact on gluten content, accounting for almost 70% of the total variation. This highlights the fact that the choice of variety is decisive for achieving a high gluten content. Previous results have shown that varieties such as Anapurna had a significantly higher gluten content compared to other varieties.

Sowing density (Factor C) has a limited effect, contributing only 4.19%. Adjusting the density can bring minor improvements, but its impact is reduced compared to choosing the variety.

The year of cultivation (Factor A) has a minimal influence (0.18%), which indicates that climatic variations between the analyzed years do not significantly affect the gluten content

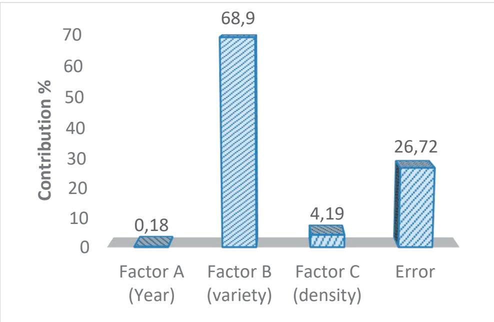

Figure 9. Contribution of factors A [crop year], B [cultivated variety], C [sowing density] to gluten content

CONCLUSIONS

The cultivated variety is the most important factor for both wheat production and its quality (protein and gluten content). The Anapurna variety stood out as the variety with the best results because it recorded a significantly higher production than the Biharia and Glosa varieties, had the highest protein and gluten content, with statistically significant differences compared to the other varieties, and the Biharia variety had intermediate results. The contribution of the variety to the variation of gluten content was 68.90%, and to the protein content of 76.47%, confirming the crucial importance of this factor in determining the quality of wheat.

Sowing density had a moderate impact on wheat production and quality because a lower density (530 g.s./m^2) led to a slight increase in protein and gluten content, but these differences were not statistically significant in most cases. The optimal density could be 650 g.s./m^2, as it provides a balance between production and quality, without significantly compromising yield. The contribution of density to gluten content was 4.19%, and to protein 10.17%, which shows that the impact of density is much lower compared to that of the variety.

The growing year, as there were no considerable climatic differences, had a negligible influence on both the production and the quality of wheat, the differences between years in terms of production, protein and gluten content were statistically insignificant. The year's contribution to gluten content was only 0.18%, and to protein 0.85%, confirming that moderate climatic variations did not significantly influence wheat.

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