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STUDIES ON THE CULTIVATION OF WHITE MUSTARD (*Sinapis alba*) UNDER THE AGROECOLOGICAL CONDITIONS OF SOUTHERN DOBROGEA – DELENI IN A CONVENTIONAL SYSTEM

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Abstract

This study explores the behavior of white mustard (Sinapis alba) varieties under the specific agroecological conditions of southern Dobrogea. The experiments were conducted in the locality of Deleni, Constanța County, on two indigenous varieties, Bella and Cezara. The same agricultural technology was applied to both varieties, with the main objectives being to determine the optimal sowing density, analyze plant density at emergence and harvest, and assess the qualitative indicators of production. The results indicate that both varieties exhibit significant adaptive characteristics to the agroecological context of the region, yielding favorable average production levels in the cultivation years of 2022, 2023, and 2024. Additionally, the findings highlight the impact of environmental factors such as precipitation levels and soil conditions on plant development and productivity. The mean and standard deviation were calculated for each crop variant (Cezara and Bella, with and without fertilizer) both at emergence and at harvest, and an ANOVA test was applied to check whether the differences between variants were statistically significant. Additionally, a student's t-test was used to compare the means between the fertilized and control variants for each variety. The results showed that the differences between variants were statistically significant ($p < 0.05$), indicating a clear effect of fertilization on the increase in the number of siliques. To verify the normality of the data distribution, the Shapiro-Wilk test was used. p-values greater than 0.05 suggest that the distribution of the number of siliques per plant follows a normal distribution, validating the applicability of the parametric tests used. A regression analysis was conducted to assess the impact of plant density on yield. Linear regressions indicated a positive correlation between plant density at harvest and the obtained yield, with significant determination coefficients (R^2). These results contribute to a better understanding of the potential of Sinapis alba in conventional farming systems and offer insights into optimizing cultivation techniques for sustainable agricultural production in this region.

Key words: *mustard, climatic factors, cultivation, fertilizer, production, Southern Dobogea.*

INTRODUCTION

The cultivation of white mustard (*Sinapis alba*) is particularly important due to its multiple uses, ranging from its phytosanitary role to its application in the food industry (Popescu & Ionescu, 2019). This plant is widely recognized for its ability to suppress soil-borne pathogens, improve soil structure, and act as a natural biofumigant, making it an essential component in sustainable agriculture (Gheorghe et al., 2022; Risnoveanu et al., 2022). Additionally, white mustard contributes to weed suppression and enhances soil fertility by increasing organic matter content and nutrient cycling (Smith & Thompson, 2017; Titei, 2022). The effectiveness of different mineral fertilization strategies has been analyzed in relation to mustard cultivation, highlighting its role in maintaining soil productivity (Suvet et al., 2024).

In Romania, this crop has been promoted as a solution for diversifying crop rotation, considering its drought resistance, high adaptability to different soil types, and short vegetation period, which allows for flexibility in planting schedules (Axinte et al., 2006; Panaitescu, 2008; Panaitescu & Niță, 2011). The adaptability of various agricultural plants to dry-farming systems in southeastern Romania has been studied, emphasizing the potential of mustard as a resilient crop (Risnoveanu et al., 2022). White mustard is also valuable due to its potential applications in biofuel production, green manure, and livestock feed, given its high protein and essential oil content (Titei, 2022). Moreover, the role of innovative seed treatments in improving germination and seedling vigor has been explored, further supporting its agronomic importance (Epure et al., 2024). Deleni, the locality where the studies were conducted, has a temperate-continental climate influenced by its proximity to the Black Sea coast, with an average annual temperature of 11.5°C and average annual precipitation below 400 mm (Ministry of Agriculture and Rural Development, 2023). This region is characterized by frequent periods of water deficit, requiring crops with strong drought tolerance to ensure stable yields. The predominant soils are chernozems, known for their high humus content, good moisture retention, and natural fertility, making them highly suitable for agricultural production (Panaitescu, 2016). Given these conditions, the selection of well-adapted mustard varieties plays a crucial role in maximizing yield potential and ensuring economic sustainability (Iosub et al., 2022).

White mustard cultivation integrates well into local agricultural systems due to its low input requirements, fast germination rate, and ability to thrive in soils with variable fertility levels (Smith & Thompson, 2017). Furthermore, its deep root system helps prevent soil erosion, improves nutrient cycling, and enhances organic matter content, contributing to long-term soil health (Jia et al., 2020). The effectiveness of different treatments in controlling crop diseases has been examined, with implications for integrated pest management strategies in mustard cultivation (Iosub et al., 2022; Toader et al., 2024). The use of thyme essential oils has also been studied for their antifungal properties, which could serve as an alternative seed treatment in sustainable mustard farming (Gheorghe et al., 2022). Recent studies have highlighted the impact of plant growth regulators on seedling morphology, further demonstrating the agronomic potential of white mustard under controlled conditions (Jia et al., 2020). Additionally, research into its fresh and ensiled biomass quality suggests promising applications in animal nutrition and fodder production (Titei, 2022). The influence of sustainable agricultural practices, including reduced pesticide use and eco-friendly fertilization techniques, is increasingly relevant in the context of climate change and environmental conservation (Toader et al., 2024).

In this context, the present study aims to analyze the agronomic performance, yield potential, and adaptability of two Romanian white mustard varieties, Bella and Cezara, cultivated under the specific conditions of southern Dobrogea. The research evaluates key parameters such as emergence density, plant development, biomass accumulation, and seed productivity, providing valuable insights into optimizing mustard cultivation in this region. The results contribute to the development of the best management practices that enhance both economic profitability and ecological sustainability in conventional farming systems.

MATERIALS AND METHODS

The experiments were conducted in Deleni, Constanța County, under the climatic conditions characteristic of southern Dobrogea. The region is known for its temperate-continental climate, influenced by its proximity to the Black Sea, which results in moderate winters and hot, dry summers. The soil in the area are predominantly chernozems, rich in humus and naturally high in fertility, making them well-suited for agricultural production. The average annual temperature is 11.5°C, while the average annual precipitation remains below 400 mm, creating a challenging environment for crop cultivation and necessitating the selection of drought-resistant varieties.

The selected varieties for this study were Bella and Cezara, both of which are included in the Official Catalogue of Plant Varieties of Romania - 2022. Cezara is a semi-late Romanian mustard variety, known for its good adaptability to arid conditions and high yield stability. Bella, also a Romanian variety, is particularly valued for its antinematode properties, making it an excellent rotation crop to improve soil health. Like Cezara, it demonstrates strong drought resistance and is classified as a semi-late variety. For each variety, Bella and Cezara, two hectares were cultivated using the same agricultural technology, alongside two control hectares for each variety, ensuring a comparative analysis of different cultivation approaches. In line with the study's goal, the following key objectives were established: Identifying an optimal cultivation technology variant that ensures high productivity and sustainability. Monitoring crop development throughout the entire vegetation period, with frequent field observations to assess plant health and growth stages. Determining key yield indicators and quality parameters of the harvested crop, including seed weight, biomass accumulation, and oil content. Additionally, the study aims to evaluate the response of these mustard varieties to the specific climatic and soil conditions of the region, providing scientific insights into their adaptability, resilience, and agronomic performance. Given the increasing concerns about climate change and soil degradation, understanding the role of mustard in sustainable agricultural systems is becoming increasingly important. By conducting a detailed analysis of plant density at emergence and harvest, seed yield, and overall productivity, this research contributes to the optimization of mustard cultivation practices in southern Dobrogea, a region where water scarcity and extreme weather events pose significant challenges to farmers.

The mean and standard deviation were calculated for each crop variant (Cezara and Bella, with and without fertilizer) both at emergence and at harvest, and an ANOVA test was applied to check whether the differences between variants were statistically significant. Additionally, a student's t-test was used to compare the means between the fertilized and control variants for each variety. The results showed that the differences between variants were statistically significant ($p < 0.05$), indicating a clear effect of fertilization on the increase in the number of siliques. To verify the normality of the data distribution, the Shapiro-Wilk test was used. p-values greater than 0.05 suggest that the distribution of the number of siliques per plant follows a normal distribution, validating the applicability of the parametric tests used. A regression analysis was conducted to assess the impact of plant density on yield. Linear regressions indicated a positive correlation between plant density at harvest and the obtained yield, with significant determination coefficients (R^2).

For each variety, Bella and Cezara, two hectares were cultivated using the same agricultural technology, along with an additional two hectares of control plots for each variety. Soil preparation included stubble breaking, autumn plowing, fertilization with complex NPK 15:15:15 fertilizers (200 kg/ha), and mechanized harvesting at full maturity when the grain moisture was below 16%. Sowing was carried out at a depth of 3 cm, with a row spacing of 25 cm and a sowing density of 120 viable seeds/m². The mustard was sown in the first urgency window each year of cultivation.

A microgranulated starter fertilizer, Microstar Care PZ NG (30 kg/ha), was also applied at sowing. This product combines essential nutrients and enhances root development and nutrient uptake, ensuring optimal early plant growth.

Crop monitoring included regular field observations, determination of plant density at emergence and harvest, and analysis of productivity indicators. Winter wheat was used as a preceding crop in all experiments. Standard agronomic maintenance practices were applied each year, including both preventive and curative measures. Weed control was carried out using Galera herbicide at a rate of 300 ml/ha in 300 liters of water. The product was applied when weeds were in their early developmental stages. After herbicide application, an additional treatment with the Alga 600™ biostimulator was performed. This product, derived from marine algae (*Sargassum* spp.), was applied at 1.5 kg/ha during the stem elongation phase to enhance plant vigor. Pest control was managed using Apis 200 SE at 250 ml/ha in 300 liters of water. Disease control was carried out using Amistar Gold fungicide at a rate of 1 liter/ha. In the control plots, neither the starter fertilizer nor the biostimulator was applied; only complex fertilizers were used. Otherwise, all other maintenance operations were identical across treatments.

Sowing followed variety-specific recommendations, maintaining a density of 120 viable seeds per m². The emergence density was assessed based on counts taken over 10 linear meters on two adjacent rows, in three repetitions along the field diagonal over the three years of study.

RESULTS AND DISCUSSIONS

If 300 viable seeds were sown per 10 linear meters, the resulting plant densities were recorded as follows: for the Cezara variety with fertilizer application, the average emergence density over three years was 84.77 plants/m², with 87.86 plants/m² in 2022, and a decline to 81.13 plants/m² in 2024 due to lower spring precipitation levels. The control variant (Cezara without fertilizer) had an average density of 76.44 plants/m², with 79.53 plants/m² in 2022, dropping to 70.26 plants/m² in 2024. A similar trend was observed for the Bella variety, with 2024 experiencing a notable decline in emergence density due to drought conditions. The three-year average emergence density for fertilized Bella was 81.30 plants/m², while the control variant had 78.19 plants/m², more data can be observed in Table 1. The data indicate a clear decrease in emergence density in 2024, primarily due to lower precipitation levels. Fertilized variants consistently demonstrated higher emergence densities compared to control plots. The application of fertilizers and biostimulators significantly improved plant establishment, highlighting their importance in mitigating the adverse effects of drought conditions.

Fertilized variants consistently demonstrated higher emergence densities compared to control plots. This underscores the role of nutrient supplementation in promoting early plant vigor, particularly under water-deficient conditions. Biostimulators and fertilizers significantly improved plant establishment, supporting: enhanced seedling vigor, leading to better survival rates, improved root system development, which may have contributed to greater resilience to soil moisture fluctuations, stronger plant growth, ensuring better competition for resources in early vegetative stages.

The data indicate a clear decrease in emergence density in 2024**,** primarily due to lower precipitation levels. The analysis suggests that years with reduced spring rainfall had a direct impact on early plant establishment, emphasizing the importance of water availability during germination and emergence stages**.**

The harvest density was determined using similar methods, resulting in an average of 66.84 plants/m² for the Cezara mustard variant with fertilizer**,** compared to only 62.26 plants/m² for the control variant**.** For the Bella variant with fertilizer**,** the three-year average density was 61.35 plants/m²**,** whereas the control variant had only 56.22 plants/m²**,** as shown in Table 2**.** The reduction in density can be attributed to factors such as soil dryness during the early vegetation period and pest attacks.

Based on these determinations, it can be stated that major importance should be given to several factors and indicators: optimizing the sowing density to 70-72 plants/m² to maximize yield, using fertilizers and biostimulants to improve plant vigor and production, closely monitoring climatic conditions, and adapting cultivation technologies to drought, especially since prolonged droughts and an increase in the average annual temperature have been recorded in the study area in recent years.

The mean and standard deviation were calculated for each crop variant (Cezara and Bella, with and without fertilizer) both at emergence and at harvest, the data can be found in Figure 1. The data indicate that the fertilized variants tend to have a higher density compared to the control variants. An ANOVA test was applied to check whether the differences between the variants are statistically significant. Emergence density: F-statistic = 1.29, P-value = 0.3431. There are no significant differences between the variants at emergence. Harvest density: F-statistic = 2.25, P-value = 0.1598. There are no significant differences between the variants at harvest. To assess the stability of density values at emergence and harvest over three years, the standard deviation was calculated: emergence density: Cezara fertilized: 3.393, Cezara control: 5.3520, Bella fertilized: 5.3425, Bella control: 7.5104. Harvest density: Cezara fertilized: 6.7464, Cezara control: 5.7694, Bella fertilized: 3.4504, Bella control: 3.3354, more date can be found in Table 3. Higher standard deviation values indicate greater variation in data from year to year. The higher standard deviation for fertilized Cezara suggests that this variant was more sensitive to climatic changes. Conversely, Bella had a lower standard deviation, indicating greater stability over time, even under more challenging conditions. Cezara appears to respond more strongly to variable climatic conditions, while Bella is more stable. However, in both cases, the application of fertilizer and biostimulant contributes to higher density at both emergence and harvest.

The determination of the number of siliques per plant was carried out in the field by selecting a representative sample of five plants along the diagonal of the field. Measurements were conducted in three repetitions along the diagonal for each variant in each cultivation year. The results of the counts are presented in the table below.

Table 1. Average emergence density of Cezara and Bella mustard varieties in control and fertilized variants with starter fertilizer and biostimulator

Year	Variety/ variant	Row 1 Plant count	Row 2 Plant count	Average per replication Plant count per row (10 linear m)	Density per square meter (plants/m²)
2022	Cezara /V1	217.33	222	219.66	87.86
	Cezara control/ V2	202.33	195.33	198.83	79.53
2023	V1	215.33	211.33	213.33	85.33
	V2	199	198.66	198.83	79.53
2024	V1	201.66	204	202.83	81.13
	V2	177.66	173.66	175.66	70.26
Average over III years	**V1**	**211.44**	**212.44**	**211.94**	**84.77**
	V2	**192.99**	**189.21**	**191.1**	**76.44**
2022	Bella /V3	212.33	213	212.66	85.06
	Bella control/V4	212.33	210.66	211.5	84.6
2023	V3	209.67	208.67	209.17	83.67
	V4	201.33	199	200.16	80.06
2024	V3	190.33	185.66	187.99	75.19
	V4	174	175.66	174.83	69.93
Average over III years	**V3**	**204.11**	**202.44**	**203.27**	**81.30**
	V4	**195.88**	**195.10**	**195.49**	**78.19**

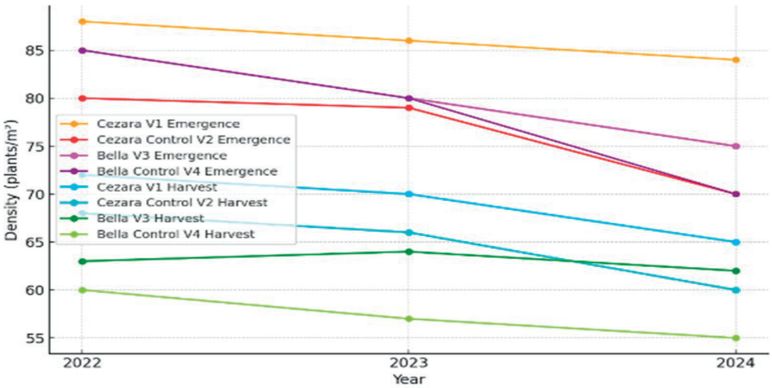

Figure 1. Evolution of density at emergence and harvest for the two mustard varieties

Table 2. Average Harvest Density of Cezara and Bella Mustard Varieties in Control and Fertilized Variants with Starter Fertilizer and Biostimulator

Year	Variety/ variant	Row 1 Plant count	Row 2 Plant count	Average per replication Plant count per row (10 linear m)	Density per square meter (plants/m²)
2022	Cezara /V1	179	179.33	179.16	71.66
	Cezara control/ V2	167	165.66	166.33	66.53
2023	V1	175.66	173	174.33	69.73
	V2	162	163	162.5	65
2024	V1	148.33	147.33	147.83	59.13
	V2	140.33	139	139.66	55.86
Average over III years	**V1**	**167.66**	**166.55**	**167.10**	**66.84**
	V2	**156.44**	**155.88**	**156.16**	**62.26**
2022	Bella /V3	154.33	159.66	156.99	62.79
	Bella control/V4	149.33	149	149.16	59.66
2023	V3	159	159	159	63.6
	V4	141.67	138.33	140	56
2024	V3	146.66	141.66	144.16	57.26
	V4	132.33	132.66	132.5	53
Average over III years	**V3**	**153.33**	**153.44**	**153.38**	**61.35**
	V4	**141.11**	**139.99**	**140.55**	**56.22**

Table 3 Statistical summary

Plant density statistical summary		
Variant	**Mean**	**Standard deviation**
Cezara V1 emergence	84.77	3.3993
Cezara control V2 emergence	76.44	5.3520
Bella V3 emergence	81.30	5.3425
Bella control V4 emergence	78.19	7.5104
Cezara V1 harvest	66.83	6.7464
Cezara control V2 harvest	62.46	5.7694
Bella V3 harvest	61.21	3.4504
Bella control V4 harvest	56.22	3.3354

For the Cezara variety with fertilizer application, the average number of siliques per plant over the three years of experimentation ranged between 130.2 and 131, with an overall mean of 130.53 siliques per plant. In contrast, for the control variant, the average number of siliques per plant over the three years varied between 117.8 and 118.46, with a three-year mean of 118.13 siliques per plant. For the Bella variety with fertilizer application, the average number of siliques per plant over the three years of experimentation ranged between 116.26 and 118.2, with an overall mean of 117.37 siliques per plant. In contrast, for the control variant, the three-year average ranged between 109.26 and 111.26, with a mean of 110.10 siliques per plant, data found in Table 4. These parameters highlight the high productive potential of these varieties despite climatic variability during the study years. Additionally, they emphasize the higher productive potential of the Cezara variety compared to the Bella variety.

Table 4. The average number of siliques per plant based on variety and variant

Year	Variety/ variant	Plants	Replication No. 1 Number of siliques per plant	Replication No. 2 Number of siliques per plant	Replication No. 3 Number of siliques per plant	Mean
2022	Cezara /V1	5	143.2	142.6	143.2	143
	Cezara control/ V2	5	134.4	133.6	133.2	133.73
2023	V1	5	132.4	131.2	133.6	132.4
	V2	5	120.6	118.8	119.6	119.66
2024	V1	5	117.4	116.8	114.4	116.2
	V2	5	98.4	103	101.6	101
Average over III years	**V1**	**5**	**131**	**130.2**	**130.4**	**130.53**
	V2	**5**	**117.8**	**118.46**	**118.13**	**118.13**
2022	Bella /V3	5	126.2	124.8	125.6	125.53
	Bella control/V4	5	121	120.2	124	121.73
2023	V3	5	123.2	120.4	121.8	121.8
	V4	5	120.4	118	119.4	119.26
2024	V3	5	123.2	120.4	121.8	121.8
	V4	5	88	89.6	90.4	89.33
Average over III years	**V3**	**5**	**117.66**	**116.26**	**118.2**	**117.37**
	V4	**5**	**109.8**	**109.26**	**111.26**	**110.10**

A regression analysis was conducted to evaluate the impact of plant density on yield (Figure 2).

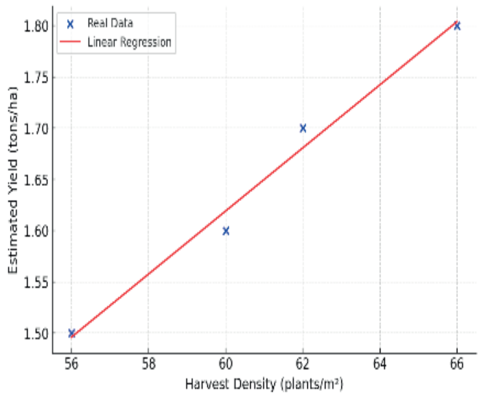

Figure 2. Graphical representation of the regression between harvest density and estimated yield

The linear regressions indicated a positive correlation between plant density at harvest and the obtained yield, with significant determination coefficients (R^2). The determination coefficient (R^2) = 0.944, meaning that 94.4% of the yield variation is explained by plant density at harvest. In other words, there is a very strong relationship between these two factors.

The regression coefficient (x1) = 0.0288, indicating that for every increase of 1 plant/m² in density at harvest, the estimated yield increases by 0.0288 tons/ha. The intercept (const) = -0.1264, which represents the point where the regression line intersects the yield axis. While it does not have a direct practical interpretation, it is necessary for the mathematical model. The p-value for the coefficient ($P>|t|$) = 0.028, which is below the threshold of 0.05, indicating a statistically significant relationship between the variables. The ANOVA results indicate a significant difference between the variants ($p < 0.05$), confirming the influence of fertilization on the number of siliques per plant. Additionally, a t-test (Student's t-test) was applied to compare the means between fertilized and control variants for each variety. The results showed that the differences between variants are statistically significant ($p < 0.05$), demonstrating a clear effect of fertilization on the increase in the number of siliques. To verify the normality of the data distribution, the Shapiro-Wilk test was used. The p-values > 0.05 suggest that the distribution of siliques per plant follows a normal distribution, validating the applicability of parametric tests. The coefficient of variation (CV%) was calculated for each variant, highlighting the variability of the data. The obtained values fall within an acceptable range (<10%), confirming the accuracy of the determinations and the reproducibility of the measurements. Thus, the higher the plant density at harvest, the higher the estimated yield.

The average grain weight per silique was 0.0177 g. according to Table 5, while the thousand grain weight (TGW) ranged between 5.23 g and 5.31 g. These results presented in Figures 3 and 4, are consistent with previous reports for this variety, confirming its genetic qualities and adaptability under moderate drought conditions. Furthermore, the low variability in TGW values suggests stable grain development, even under fluctuating environmental conditions. This indicates a good balance between plant resource allocation and grain filling efficiency, contributing to overall yield stability.

Table 5. The average grain weight per silique per plant based on variety and variant

Year	Variety/ variant	Plants	Replication No. 1 grain weight per silique, g	Replication No. 2 grain weight per silique, g	Replication No. 3 grain weight per silique, g	Mean
2022	**Cezara /V1**	10	0.0219	0.0215	0.0214	0.0216
	Cezara control/ V2	10	0.0197	0.0196	0.0197	0.01966
2023	**V1**	10	0.0191	0.0188	0.0187	0.0188
	V2	10	0.0164	0.0159	0.0153	0.01586
2024	**V1**	10	0.0167	0.0163	0.0171	0.0167
	V2	10	0.0132	0.0122	0.0128	0.01273
Average over 3 years	**V1**	**10**	**0.0192**	**0.0188**	**0.0190**	**0.0190**
	V2	**10**	**0.0164**	**0.159**	**0.0159**	**0.01606**
2022	**Bella /V3**	10	0.0221	0.0215	0.0212	0.0216
	Bella control/V4	10	0.0185	0.0184	0.0187	0.01853
2023	**V3**	10	0.0184	0.0186	0.0184	0.01846
	V4	10	0.0161	0.0156	0.0152	0.01563
2024	**V3**	10	0.0164	0.0162	0.0161	0.01623
	V4	10	0.0129	0.0124	0.0122	0.0125
Average over III years	**V3**	**10**	**0.0189**	**0.0187**	**0.0185**	**0.0187**
	V4	**10**	**0.0158**	**0.0154**	**0.0153**	**0.0155**

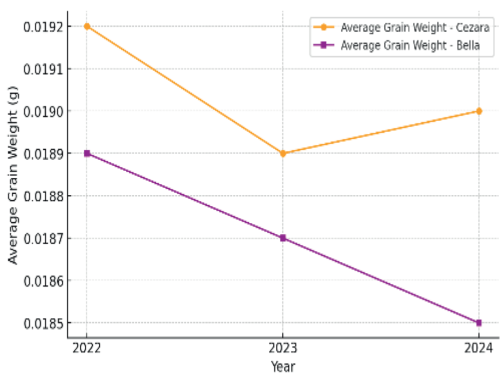

Figure 3. Evolution of the average grain weight of white mustard

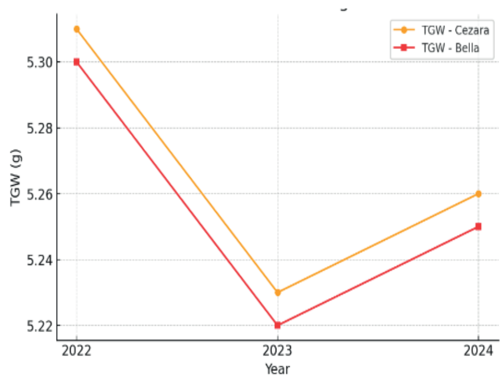

Figure 4. Evolution of the thousand grain weight of white mustard

The calculation of probable yield represented in Figure 5 highlighted an estimated productivity of approximately 1.8 tons/ha for the Cezara variety. This value aligns with the genetic potential of the variety and the agroclimatic conditions of the study year. Additionally, the stability of this yield suggests an efficient resource utilization and a good adaptation of the variety to environmental factors. The results confirm that Cezara maintains a high production potential, making it a reliable choice for cultivation under similar conditions.

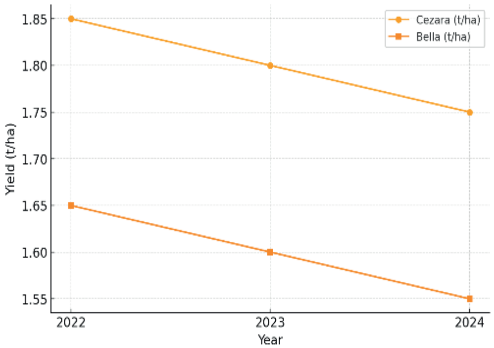

Figure 5. Evolution of White Mustard Yield

CONCLUSIONS

The study demonstrated that the Bella and Cezara varieties adapt efficiently to the agroecological conditions of southern Dobrogea. The Cezara variety exhibited higher productivity compared to Bella, confirming its status as a climate-resistant variety well-suited to the specific conditions of the region. Additionally, the statistical analysis revealed significant correlations between plant density and yield, indicating that the application of fertilizers and biostimulants can contribute to achieving higher yields. Recommendations for yield optimization: optimizing sowing density to 70-72 plants/m² to maximize yield, using fertilizers and biostimulants to enhance plant vigor and production, carefully monitoring climatic conditions and adapting cultivation technologies to drought, introducing complementary varieties for genetic diversification and production stability and implementing sustainable agricultural practices for soil conservation and maintaining fertility.

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