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ASSESSMENT OF THE IMPACT OF MINIMUM TILLAGE TECHNOLOGY ON SOIL PROPERTIES AND WINTER WHEAT YIELD UNDER THE PEDOCLIMATIC CONDITIONS OF POARTA ALBĂ, CONSTANȚA COUNTY (2021–2024)

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Abstract. *This study evaluates the impact of minimum tillage technology on the yield and quality of winter wheat (Triticum aestivum L.) under the specific pedoclimatic conditions of Poarta Albă, Constanța County, during the 2021–2024 period. The research focused on two cultivars: Katarina and Avenue, grown on areas ranging from 110 to 140 hectares annually, using a conservation tillage system supplemented with irrigation during critical growth stages. Measurements were carried out for plant density, number of grains per spike, thousand-kernel weight, spike weight, test weight, and yield per hectare. Despite annual climatic variability, yields remained high and stable: 8,730 kg/ha for the Avenue cultivar and 8,250 kg/ha for Katarina. Statistical analysis revealed a weak correlation between climatic parameters (temperature, precipitation) and yield, suggesting that minimum tillage technology, combined with irrigation, played a key role in mitigating abiotic stress. The minimum tillage system contributed to water conservation in the soil, reduced erosion, and maintained soil structure, creating a favorable environment for crop development. By minimizing mechanical interventions and protecting the topsoil layer, this technology demonstrated superior agronomic and economic efficiency under conditions of moderate drought. The results support the adoption of this system as a sustainable strategy in regions facing high climatic risk, confirming its role in maintaining both yield and production quality.*

Keywords: *wheat, minimum tillage, yield, soil, climatic factors*

INTRODUCTION

In recent decades, modern agriculture has been undergoing a continuous transition toward technologies that meet the demands of sustainability, efficiency, and environmental protection (SIN et al., 2003; FERENCZI and BODNAR, 2024). One such direction is the adoption of minimum tillage systems—an agricultural technology that reduces the intensity of soil operations to conserve natural resources, particularly soil and water. This method is increasingly adopted by both European and Romanian farmers, promoted for its benefits on soil quality as well as for the economic efficiency of the crops grown under such systems.

In the scientific literature, minimum tillage is defined as a form of conservative soil management that involves reducing mechanical interventions to a minimum while maintaining an effective capacity for crop residue incorporation and seedbed preparation (PETCU & PETCU, 2008; PANAITESCU, 2016). This system is distinguished by its lower impact on soil structure compared to conventional plowing, thus ensuring better moisture retention and organic matter conservation (STROE & MIRON, 2025).

In Romania, numerous studies have focused on the influence of minimum tillage on yield and soil quality in cereal crops. SĂULESCU and SĂULESCU (2011) highlight that conservation technologies can sustain high wheat yields, especially in the arid conditions of the southern and southeastern regions of the country (GACIU, 2025). Recent studies (MARIN et al., 2015; COCIU et al., 2017; CHEȚAN & CHEȚAN, 2021) confirm that minimum tillage positively affects soil structure by maintaining better aggregation and aeration, and by reducing compaction and water loss.

Furthermore, winter wheat (*Triticum aestivum* L.), one of the most widely grown crops in Romania, responds well to this soil management system, particularly in areas with low precipitation and erosion-prone soils. According to ROMAN et al. (2006) and PANAITESCU & NIȚĂ (2011), the application of minimum tillage in wheat cultivation contributes to reduced production costs, improved yield stability, and decreased mechanical impact on the soil.

Internationally, research by RITCHIE et al. (2022) shows that in the context of climate change, the conservation of natural resources through technologies such as minimum tillage is essential for maintaining yields in staple crops, including wheat. Additionally, YAHELIUK et al. (2024) specifically highlight the response of cereal crops to modern technologies, noting the global shift toward conservation agriculture as an adaptive response to climatic volatility and the growing demand for both economic and environmental efficiency. MANESCU et al. (2022) and POPESCU et al. (2022; ILJKIĆ et al., 2024) add to this perspective by analyzing the impact of climate change on the yields of wheat, maize, and sunflower in Romania, and suggest the implementation of adaptive agricultural practices such as minimum tillage to mitigate these effects (MANOLE et al., 2023).

In this context, studying the effects of minimum tillage technology in high agricultural potential areas exposed to drought and soil degradation, such as Dobrogea, becomes essential (MANOLE et al., 2018).

Dobrogea is located in southeastern Romania, bordered by the Danube River and the Black Sea, surrounded by water on three sides. Constanța County, covering an area of 7,055 km², comprises the central and southern parts of the region and holds significant agricultural importance. Within the county, the commune of Poarta Albă is centrally located, lying on both sides of the Danube–Black Sea and Poarta Albă–Midia Năvodari canals. It borders the commune of Castelu to the north, the town of Ovidiu to the east, the municipality of Medgidia to the west, and the town of Murfatlar to the south.

The agricultural area of the commune totals 4,406 hectares, of which 3,344 ha are arable land, 225 ha are pastures, and 926 ha are vineyards. The relief is typical of the Dobrogea Plateau, with gentle hills and wide undulations, forming part of the Medgidia Plateau. The region is crossed by the Carasu Valley and characterized by a mild climate, with an average annual temperature of 10.8°C and an average precipitation of 426.5 mm/year. The predominant soils are calcareous and semi-calcareous chernozems, fertile but prone to erosion and degradation under intensive soil management.

Therefore, analyzing the application of minimum tillage technology in the Poarta Albă area is relevant both for adapting to local climatic conditions and for increasing the sustainability of wheat production. Available data and previous research support the hypothesis that this technology can be a viable solution for maintaining soil fertility and yield under responsible agricultural practices.

MATERIAL AND METHODS

The research was conducted between 2021 and 2024 on the agricultural holding *Intreprindere Individuală Pușcuță*, located in the commune of Poarta Albă, Constanța County, Romania. Established in 2004, the farm has experienced steady growth, expanding from an initial

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50 hectares under lease to approximately 250 hectares of agricultural land, of which 100 hectares are owned and the remainder leased. The land is consolidated into compact parcels of about 40 hectares, which facilitates the efficient implementation of modern technologies.

Irrigation access is ensured through connection to the Danube–Black Sea Canal, and since the winter of 2021, the farm has been equipped with a high-performance irrigation system covering approximately 150 hectares. This system includes three IRTEC G/F10 110/550 hose reels equipped with solar panels, electric valves, corn risers, and REFLEX 600 water cannons, powered by three IRTEC I75R702 (75 HP) motor pumps. The hydrant network measures 1,300 m and 1,200 m along two main lines, with hydrants installed at regular 52-meter intervals.

The farm is equipped with a fleet of modern machinery guided by GPS systems, enabling high-precision agricultural operations and detailed archiving of operational data. This contributes to the development of a relevant database, essential for the consistent application of minimum tillage technology. In this system, equipment such as independent disc cultivators for shallow loosening, disc harrows for seedbed preparation, precision seeders adapted for reduced tillage, and localized fertilizer applicators are used. These tools play a vital role in preserving soil structure, reducing compaction, and retaining moisture within the soil profile.

In the current context of climate change, marked by an increase in extreme weather events, decreased rainfall, and temperature instability, the adoption of minimum tillage is not merely a technological option but a strategic necessity. This system addresses the need to adapt to increasingly harsh climatic conditions, offering solutions for maintaining soil productivity and mitigating crop water stress.

During the study period, the farm cultivated winter wheat (*Katarina* and *Avenue* cultivars), barley (*SU Ellen*), field peas (*Nicoleta*), and sunflower (*LG 55.55 CLP* hybrid). This study focused on the agronomic performance of the winter wheat cultivars Katarina and Avenue under minimum tillage conditions in the pedoclimatic context of the Dobrogea region.

Katarina is a semi-dwarf variety (77–90 cm tall) with a white, awnless spike and excellent lodging resistance. It is noted for its favorable balance between quantity and quality, making it suitable for southern and southeastern Romania, including Dobrogea. Avenue is one of the earliest-maturing varieties available on the market, also awnless, and exhibits strong avoidance of thermal stress due to its adapted phenology, making it ideal for sowing during the latter part of the optimal planting window.

To achieve the objectives of this research, the following agrobiological and technological determinations were performed: plant density at emergence and harvest; in-field assessment of biological purity; analysis of thousand-kernel weight; determination of test weight; measurement of average yield per hectare; and evaluation of grain quality indicators (protein content, gluten, moisture).

All measurements were conducted in accordance with nationally and internationally accepted methodological standards, using certified laboratory equipment and appropriate statistical methods for accurate interpretation of experimental data. The results were subjected to rigorous statistical analysis using ANOVA (Analysis of Variance) to assess the significance of differences between experimental variants and validate the conclusions drawn.

RESULTS AND DISCUSSION

The research was conducted between 2021 and 2024 on the agricultural holding II Pușcuță, located in the commune of Poarta Albă, Constanța County. The farm cultivates approximately 250 hectares of agricultural land (100 ha owned and 150 ha leased), with consolidated plots and access to irrigation through the Danube–Black Sea Canal. The irrigation system includes IRTEC G/F10 hose reels equipped with solar panels and REFLEX 600 water cannons, as well as IRTEC I75R702 motor pumps. The hydrant network covers the entire surface designated for irrigated crops.

The farm's technological approach is based on the minimum tillage system, supported by a fleet of modern machinery equipped with GPS and data archiving systems. Soil preparation was performed using a Horsch Terrano cultivator in a single pass, allowing for the incorporation of crop residues and loosening of the topsoil. Sowing took place in the first ten days of October, using an Amazone Cirrus seed drill adapted to conservation tillage. The seeding density was 510 viable seeds/m² (equivalent to 210 kg/ha), with a sowing depth of 4 cm and row spacing of 12.5 cm.

Winter wheat was cultivated on an area ranging from 110 to 140 hectares annually, using the Katarina and Avenue varieties (see Fig. 2), both following rapeseed as the preceding crop. Basic fertilization consisted of applying 200 kg/ha of DAP 18.46.0 before seedbed preparation, followed by two ammonium nitrate applications: 200 kg/ha in March and 100 kg/ha in April. Weed and disease control was performed using specific herbicides and fungicides, while pest protection included both preventive and curative insecticide treatments.

Under the specific climatic conditions of Dobrogea, characterized by thermal instability and often deficient rainfall—three irrigation applications were carried out (in october, march, and may), each with a norm of 300 m³/ha, in order to compensate for soil moisture deficits.

The climatic data collected during the study period indicate significant deviations from the multiannual average, with monthly mean temperatures during the vegetation months (september–june) consistently exceeding normal values. The average temperature recorded between 2021 and 2024 was 12.35°C, compared to the multiannual norm of 9.22°C, representing an increase of over 3°C, as shown in Table 1. Notable differences were observed during the winter months, particularly January and December, where average temperatures were over 5°C higher than normal. While this had a positive influence on the vernalization process, it also increased the risk of disease development.

Precipitation, on the other hand, was unevenly distributed, totaling 336.7 mm over the analyzed period, compared to the multiannual average of 368.8 mm. Although surpluses were recorded in January and April, they did not offset the overall deficit throughout the rest of the period. This irregular distribution necessitated the application of irrigation during critical growth stages, thus ensuring the maintenance of a normal physiological rhythm for the wheat crop

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Table 1

The value of precipitation and temperatures in the experimental area during the wheat growing season in the years 2021-2024

Year	Luna	Precipitation(mm)		Monthly mran temperatures	
		Multiannual average	2021-2024	Multiannual average	2021-2024
2022	IX	41,6	30,2	17,6	22,2
2022	X	30,2	27,8	12	17,4
2022	XI	40,4	39,5	7,2	10,0
2022	XII	34,0	20,3	2,3	5,0
2023	I	31,0	45,2	0,5	6,0
2023	II	33,0	10,8	1,3	3,8
2023	III	21,7	23,6	4,2	8,1

2023	IV	33,5	99,5	10,5	10,8
2023	V	50,2	11,4	16,2	17,4
2023	VI	53,2	28,4	20,4	22,8
Sum/ year mean/year	10	368,8	336,7	9,22	12,35

Harvesting was carried out at the end of June using a Claas Tucano 320 combine harvester, when grain moisture content ranged between 11.5% and 12.8%. After threshing, the wheat was stored at a grain collection facility. The average yields recorded were 8,250 kg/ha for the Katarina variety and 8,730 kg/ha for the Avenue variety, highlighting a high production potential under conservation tillage and the specific climatic conditions of the Dobrogea region.

The application of minimum tillage technology in the pedoclimatic context of Dobrogea was based not only on the principles of water conservation and soil structure preservation, but also on the need to adapt to an increasingly unpredictable climate regime. The climatic factors recorded during the vegetation period (September–June) of the 2021–2024 agricultural years showed a significant deviation from the multiannual average, with an average temperature increase of 3.13°C (from 9.22°C to 12.35°C), as illustrated in Figure 1.

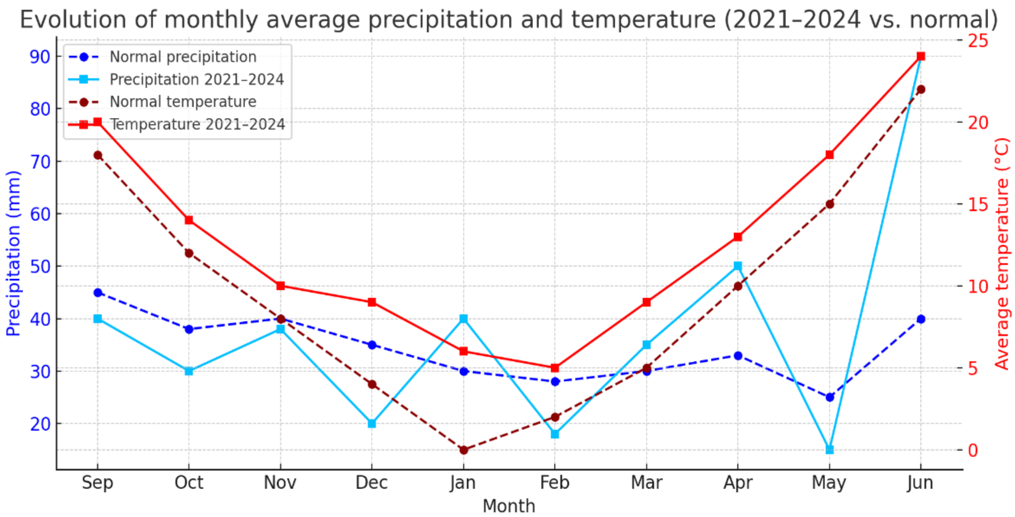

Figure 1 – Combined chart showing both the evolution of monthly average precipitation and temperature, comparing normal values with the averages from the 2021–2024 period.

This warming favored faster vegetative development during the early growth stages but also increased the risk of soil water evaporation and the occurrence of fungal diseases during the spring. Additionally, a decrease in total precipitation was observed (336.7 mm compared to 368.8 mm), with an uneven distribution. While January and April recorded values above the multiannual average, the remaining months were marked by a pronounced rainfall deficit. This imbalance necessitated supplemental water through irrigation during critical vegetation stages.

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Despite these climatic challenges, the results obtained were remarkable. The recorded harvest yields—8,250 kg/ha for the Katarina variety and 8,730 kg/ha for the Avenue variety—confirm the efficiency of minimum tillage technology when combined with rigorous and locally adapted crop management.

Plant density at emergence revealed a slight reduction compared to the initial seeding density, which is expected under field conditions. Observations were made by counting plants along 8 adjacent rows, each one meter in length, with three replications per variety. The seeding density was 510 viable seeds/m². At emergence, when the plants had developed their first true leaf, an average of 481 emerged plants/m² was recorded for the Avenue variety and 478 plants/m² for Katarina. Minimum and maximum values observed per linear meter ranged from 56 to 66 plants for Avenue and 55 to 65 plants for Katarina. These results suggest good germination capacity and high emergence uniformity in both experimental variants (Figure 2).

Final crop density at harvest was assessed through direct field observations during the soft dough stage of wheat. The method involved counting the number of spikes along one linear meter across 8 adjacent rows, with multiple replications for each variety. This approach allowed for an accurate evaluation of final crop density, expressed as spikes per square meter.

The results showed an average of 700 spikes/m² for the Avenue variety and 683 spikes/m² for the Katarina variety. On a single row, one meter in length, the number of spikes ranged from 82 to 94 for Avenue and from 80 to 89 for Katarina. These values indicate a good preservation of plant density from emergence to harvest, reflecting the adaptability of the varieties and the efficiency of the applied technology under the specific climatic conditions of the Dobrogea region (Figure 3).

During the determinations, the crop displayed very good biological purity, with only occasional isolated plants of awned wheat and wild oats being identified and removed manually.

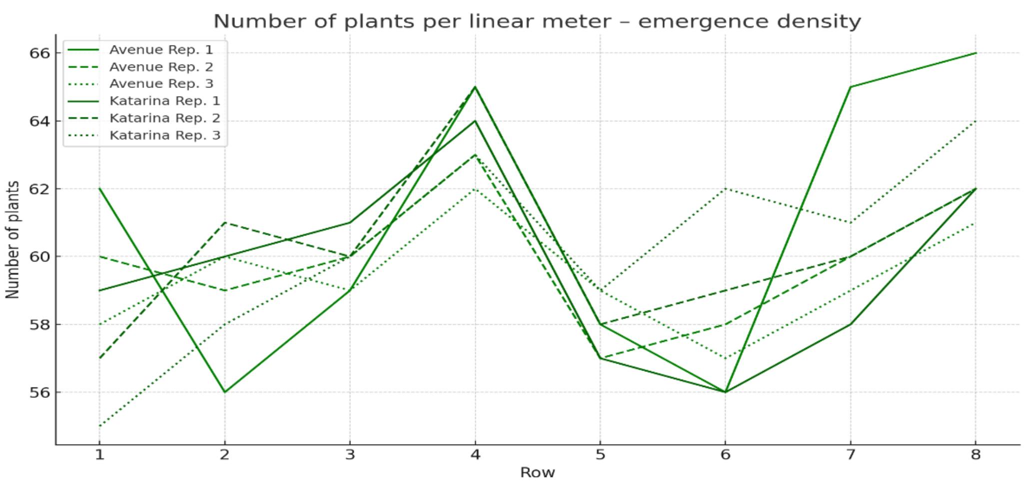

Figure 2 – Graph of emergence density values for the Avenue and Katarina varieties

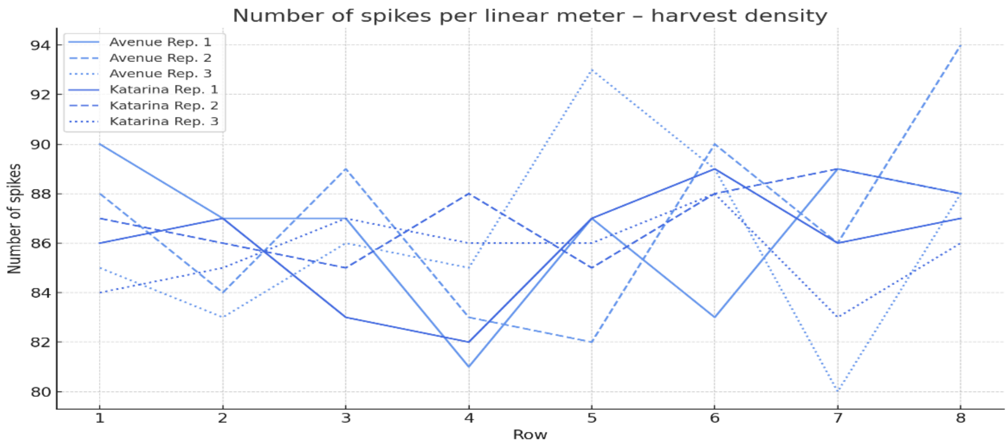

Figure 3 - Graph of harvest density values for the Avenue and Katarina varieties

To achieve this objective, samples were collected and analyzed in the crop science laboratory of the faculty, focusing on determining the average number of grains per spike and the average weight of a spike. Measurements were conducted in multiple replications for each experimental variant to ensure the representativeness of the results.

For the Avenue variety, an average of 56 grains/spike was recorded, with variations ranging from 54 to 59 grains. In the case of Katarina, the average was 54 grains/spike, with a minimum of 50 and a maximum of 58 grains. Regarding the average spike weight, it was 2.52 grams for Avenue and 2.26 grams for Katarina. These results indicate good spike fertility in both varieties, with a slight advantage for Avenue in terms of both grain number and individual spike mass (Figure 4).

To determine the thousand-kernel weight (TKW), multiple samples were taken from each experimental variant, and an average was calculated for each variety. The results showed an average TKW of 45 g for Avenue and 42 g for Katarina (Figure 5).

The values recorded correlate favorably with harvest density, the number of grains per spike, and average spike weight, reflecting a high productive capacity. Moreover, the application of irrigation during critical phases of the vegetation period played a decisive role in supporting physiological processes, which led to yields of 8,730 kg/ha for Avenue and 8,250 kg/ha for Katarina.

As for test weight, laboratory analyses showed values of 75.7 kg/hl for Katarina and 81.1 kg/hl for Avenue, confirming a superior grain quality, especially in the case of the latter variety.

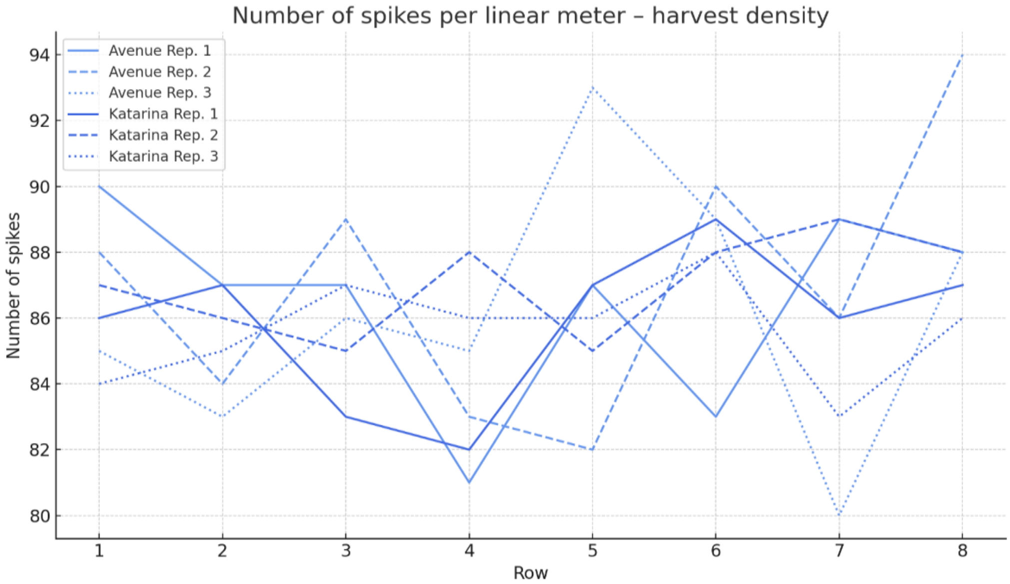

Figure 4 - Graph of the number of grains per spike for the Avenue and Katarina varieties

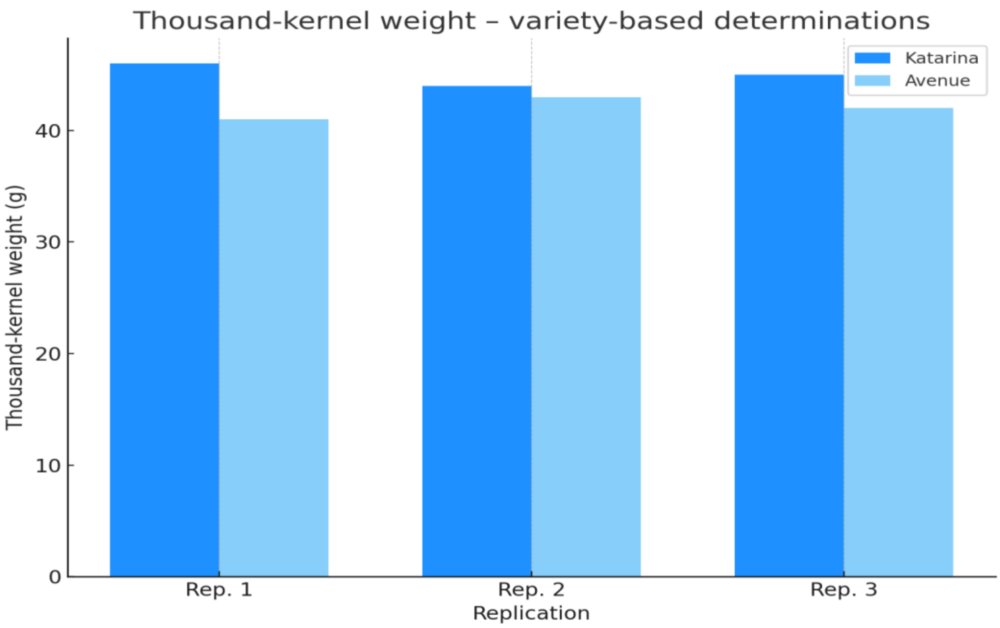

Figure 5 - Graph of thousand-kernel weight values for the Avenue and Katarina varieties

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To assess the impact of climatic factors on the thousand-kernel weight (TKW), a statistical analysis was conducted based on data recorded between 2022 and 2024 for the two studied varieties: Avenue and Katarina. Pearson correlations between TKW and the main climatic factors (mean temperature and total precipitation) revealed very weak, statistically insignificant relationships.

For the Avenue variety, the correlation coefficient between TKW and mean temperature was $r = 0.038$, and $r = –0.089$ for precipitation. In the case of Katarina, the values were $r = 0.162$ for temperature and $r = –0.212$ for precipitation. These coefficients indicate no significant climatic influence on kernel weight.

This lack of significant correlation is explained by the use of a modern, conservation-oriented technology—minimum tillage, supplemented with targeted irrigation. The minimum tillage system helps maintain soil moisture, preserves soil structure, and reduces abiotic stress on crops, resulting in consistent yields and superior grain physiological quality, regardless of annual climate fluctuations.

The Pearson correlation analysis also showed a very weak relationship between grain yield and climatic variables, namely mean temperature and annual precipitation, for both varieties. For Avenue, the correlation between yield and temperature was $r = –0.03$, and $r = –0.02$ for precipitation. Similar values were observed for Katarina ($r = –0.026$ for temperature and $r = –0.025$ for precipitation), indicating an insignificant influence of these climatic factors on actual yields.

This lack of direct correlation can be attributed to the use of advanced minimum tillage technology combined with supplemental irrigation. In each of the agricultural years analyzed, three strategic irrigations were applied during critical growth stages (autumn, early spring, and pre-heading), with rates of 300 m³/ha, which ensured a balanced water supply for the crops. Thus, yields remained stable despite annual climate variability, underlining the critical role of minimum tillage in maintaining high agricultural performance under the climatic conditions of Dobrogea.

To highlight the direction and strength of the relationships between TKW and climatic factors (mean temperature and precipitation), simple linear regression models were applied for the 2022–2024 period. Although the dataset includes only three agricultural years, the resulting equations offer an indicative perspective on existing trends.

For Avenue, TKW showed a slight positive trend with temperature, according to the equation:

$TKW = 41.82 + 0.26 \times T\ (°C)$,

while with precipitation, the trend was slightly negative:

$TKW = 46.09 – 0.005 \times P\ (mm)$.

For Katarina, the variation in TKW was slightly more sensitive to temperature:

$TKW = 29.92 + 0.98 \times T$,

and showed a more pronounced decrease under higher precipitation conditions:

$TKW = 44.32 – 0.0107 \times P$.

However, the very low R^2 values (indirectly derived from weak correlation coefficients) show that these relationships are not statistically significant. The results reinforce the idea that, under a modern minimum tillage system combined with controlled irrigation, climatic parameters did not decisively influence thousand-kernel weight, and yields remained stable despite annual fluctuations.

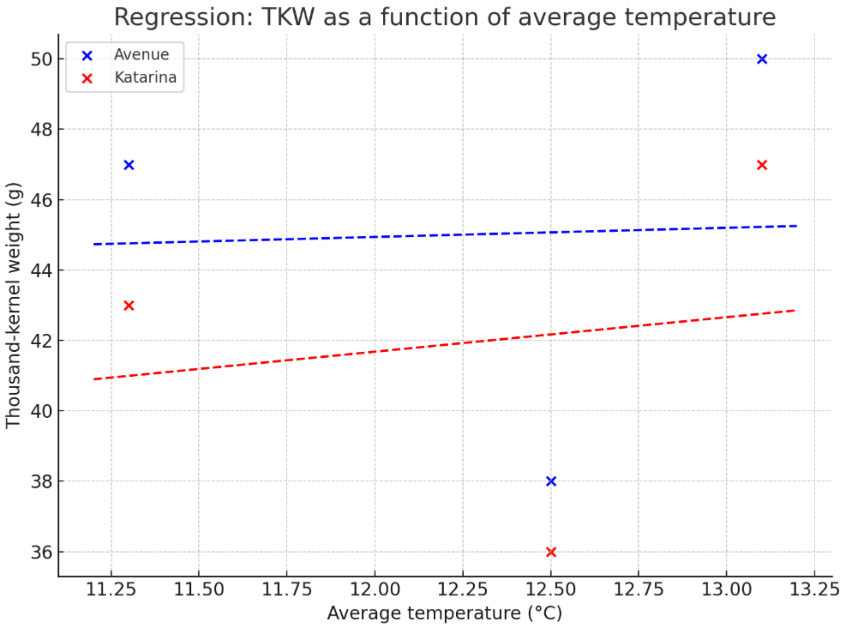

Figure 6 - Regression: TKW as a function of average temperature

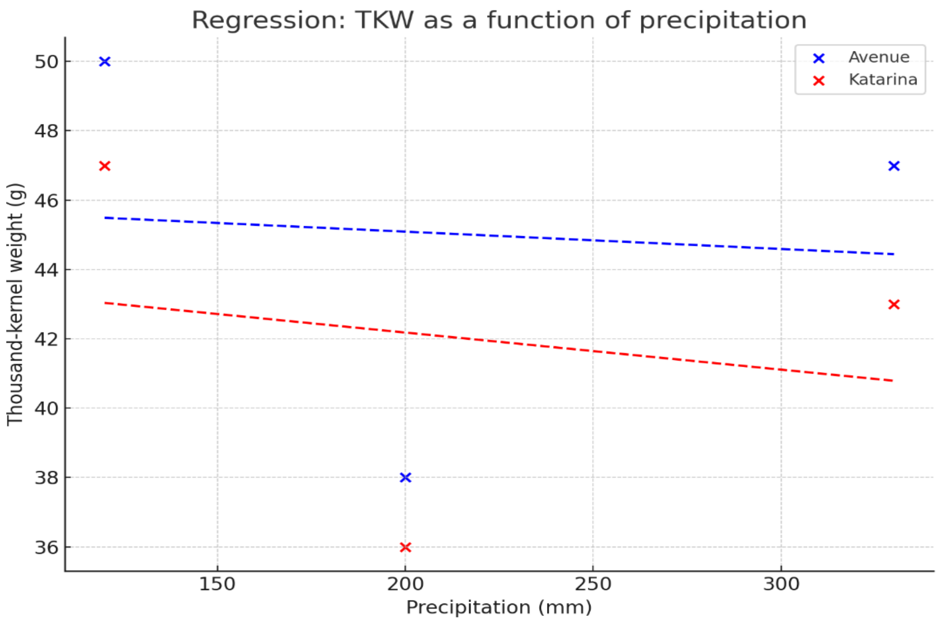

Figure 7 - Regression: TKW as a function of precipitation

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CONCLUSIONS

The research conducted between 2021 and 2024 on the agricultural holding located in the commune of Poarta Albă clearly highlighted the benefits of implementing minimum tillage technology in winter wheat cultivation under the specific pedoclimatic conditions of the Dobrogea region. The minimum soil tillage system, combined with strategically applied irrigation during critical plant development stages, played an essential role in stabilizing yields and maintaining the physiological quality of the grains, regardless of annual climate variability. The comparative analysis of the two studied varieties—Avenue and Katarina—demonstrated good adaptability within the conservation system, with average yields of 8,730 kg/ha for Avenue and 8,250 kg/ha for Katarina, confirming their high agronomic potential under conditions of technological advancement and adaptation to water stress. Morphoproductive measurements (emergence density, harvest density, number of grains per spike, spike weight, thousand-kernel weight, and test weight) supported this conclusion by consistently and vigorously expressing yield components.

As for the influence of climatic factors on yield and thousand-kernel weight, the calculated correlation coefficients ($r < 0.2$) indicated a weak and statistically insignificant relationship. Likewise, the linear regressions performed for these parameters served only as indicative models, given the limited dataset (three agricultural years). These results support the idea that minimum tillage technology, when supplemented with controlled irrigation, can significantly mitigate the negative effects of climatic variability on wheat crops, ensuring consistent yields and stable grain quality over time.

In conclusion, it can be stated that the minimum tillage system represents a viable and sustainable alternative for agriculture in the Dobrogea region, contributing to the conservation of soil resources, improving input efficiency, and maintaining yields in the context of increasingly pronounced climate change.

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