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EVALUATION OF THE PERFORMANCE OF WHEAT VARIETIES UNDER MINIMUM TILLAGE SYSTEM IN THE PEDOCLIMATIC CONDITIONS OF SĂCELE AREA, CONSTANȚA COUNTY (2021-2024)

Traian Ciprian STROE[1, 2], Oana MIHAI FLOREA[1], Liliana PANAITESCU[1, 2]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Ovidius University of Constanța, University Alley, Campus building B, Constanța, Romania

Corresponding author email: str_ciprian@yahoo.com

Abstract

This study aimed to evaluate the performance of several winter wheat (Triticum aestivum L.) varieties cultivated under the minimum tillage system in the semi-arid pedoclimatic conditions of Săcele, Constanța County (Romania) during the 2021-2024 agricultural years(October-July cropping cycles). The experimental design included four varieties: Avenue, Katarina, Rubisko, and Sorrial, monitored under variable rainfall regimes (330 mm in 2021-2022, 380 mm in 2022-2023, and <290 mm in 2023-2024). Morpho-productive parameters such as tillering capacity, plant height, grain number per spike, grain mass per spike, thousand kernel weight (TKW), and test weight (TW) were analyzed. The results represent the mean values of three consecutie agricultural years, highlighting varietal stability and adaptability under drought stress.

Among the tested varieties, Rubisko showed the highest productivity (5.9 t/ha), followed by Avenue (5.5 t/ha), Sorrial (5.0 t/ha), and Katarina (4.3 t/ha). Strong positive correlations were recorded between yield and TKW ($r = 0.94$), yield and TW ($r = 0.91$), and yield and NDVI ($r = 0.97$). The linear regression analysis confirmed a significant relationship ($R^2 = 0.93$, $p < 0.05$) between NDVI and yield, demonstrating that vegetation indices derived from multispectral UAV imagery and Sentinel-2 satellite data provide reliable and complementary information for predicting wheat yield under the studied conditions.

The study demonstrates that combining minimum tillage with precision agriculture technologies ensures sustainable and resilient wheat production in arid regions. The results support the integration of digital monitoring, biofertilization, and site-specific management as key components of climate-smart agriculture for southern Romania and similar environments.

Key words*: drought, minimum tillage, NDVI, precision agriculture, Triticum aestivum.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important field crops worldwide, playing a fundamental role in human nutrition due to its high nutritional value and technological versatility. In recent decades, adapting wheat cultivation to increasingly variable and often extreme environmental conditions has become a global agricultural priority (Xiong et al., 2024; Arif et al., 2025). Under the current climate change context: characterized by prolonged drought, heat stress, and large thermal fluctuations, enhancing wheat resilience through variety selection and sustainable technologies represents a strategic direction for agricultural development (Nyaupane et al., 2024; Shaheen et al., 2025). In the current context of accelerated climate change, the increase in land surface temperatures and the intensification of aridization processes are exerting growing pressure on agricultural systems, particularly in regions with high climatic vulnerability. Recent global-scale analyses highlight that changes in thermal and hydrological regimes directly affect agricultural productivity, ecosystem stability, and food security, generating significant economic and social impacts (Buzatu et al., 2024). At the same time, at the national level, the dynamics of land resources and the progressive degradation of soils require the adoption of sustainable conservation strategies aimed at reducing the negative effects of intensive agricultural practices on soil structure and fertility. In Romania, the implementation of conservative technologies and soil protection practices is considered essential for preventing physical and chemical soil degradation and for

adapting agricultural production systems to the new climatic conditions (Buzatu et al., 2023).

In Romania, winter wheat holds a significant share in the cropping structure, being cultivated across all agricultural regions. In the Dobrogea area, particularly around Săcele, Constanța County, the pedoclimatic conditions are distinctive, with low annual precipitation (350-450 mm), high summer temperatures frequently exceeding 35°C, and frequent dry winds factors that necessitate adapting cultivation technologies (Pascu, 2012; Partal et al., 2023). The dominant soils are cambic and leached chernozems, with medium to high natural fertility but prone to water loss through evaporation and structural degradation if excessively tilled.

In this context, the minimum tillage system, based on reducing soil disturbance and maintaining crop residues on the surface, has become a modern and sustainable technological solution for conserving soil water and fertility (Leonte et al., 2024; Dinuta et al., 2025). By decreasing the number and depth of tillage operations, this system helps preserve soil moisture, protect beneficial microorganisms, and reduce fuel and labor costs. Furthermore, it provides a favorable framework for the implementation of precision agriculture technologies, enabling optimized sowing, fertilization, and plant protection through the use of sensors and satellite data (Raza et al., 2025a; Haseeb et al., 2025).

Recent research conducted in southern Romania has demonstrated that conservative soil management systems such as minimum tillage, no-tillage, and strip-tillage practices, do not significantly reduce yields when adapted and resilient wheat varieties are used (Gheorghe & Nicolae, 2023; Nita et al., 2024). Studies performed at the Albota and Brăila research stations revealed that modern cultivars such as Izvor, Ursita, and Glosa maintain high productivity even under limited rainfall conditions (Ghiorghe et al., 2024; Dinuta et al., 2025). Moreover, the application of effective disease control treatments adapted to new climatic conditions plays a key role in ensuring yield stability (Grigoraș et al., 2012; Cioineag & Cristea, 2015; Iosub et al., 2022).

The integration of precision agriculture elements, such as UAV-based crop monitoring and remote sensing approaches (satellite-based observations), opens new perspectives for optimizing wheat crop management (Joshi et al., 2024; Qosimov & Imomov, 2025). Comparative analyses of conventional and organic systems, based on field experiments and long-term assessments, further indicate that conservative technologies such as: minimum tillage, no-tillage, and strip-tillage, as well as residue retention, reduce environmental impact while improving the sustainability of agricultural production (Kheiralipour et al., 2024; Zorovski, 2024).

Considering these aspects, the present study aims to evaluate the performance of several wheat varieties under the minimum tillage system in the pedoclimatic conditions of Săcele, Constanța County, during the 2021-2024 period corresponding to three consecutive agricultural years (October 2021 - July 2022, October 2022 - July 2023, and October 2023 - July 2024). The main objective is to identify the most adaptable varieties and the optimal technological practices within the minimum tillage system for achieving high, stable, and sustainable yields under the arid and variable climatic conditions characteristic of southern Dobrogea where Săcele is located. The results will contribute to the scientific foundation of regional strategies promoting sustainable agricultural practices and efficient use of local pedoclimatic resources, by supporting variety selection, optimizing minimum tillage management, and improving data-driven decision-making under arid conditions.

MATERIALS AND METHODS

The present research was carried out within an agricultural holding located in Săcele, Constanța County, an area representative of southern Dobrogea, characterized by pedoclimatic conditions specific to the semi-arid regions of southeastern Romania (Stroe et al., 2025; Stroe et al., 2026). The area is distinguished by a moderately continental climate with marine influences, hot and dry summers, and relatively mild winters, where the annual rainfall is low, generally ranging between 350 and 450 mm. Under such conditions, the choice of cultivation technology and the selection of suitable varieties are essential for ensuring production stability.

The study area is located in the southern part of Constanța County, near the locality of Săcele, at an average altitude of 25-30 m, within the Dobrogea Coastal Plain. The relief is slightly fragmented, predominantly flat, and favorable for intensive mechanization and precision agriculture practices. The proximity to the Black Sea creates a distinct climatic influence, with very hot and dry summers, frequent winds, and high evapotranspiration rates, making this region one of the most vulnerable agricultural areas in Romania to the process of aridization.

The regional climate is continental-excessive with Pontic influences, characterized by large thermal amplitudes and a low rainfall regime. The multiannual mean air temperature is approximately 11.3°C, but recent years have shown a steady warming trend, consistent with regional climatic observations reported by Shi et al. (2025) and Xiong et al. (2024). During the analyzed period, the annual mean temperature ranged between 11.8°C and 12.9°C, with clear positive deviations from the long-term average, particularly in the 2022-2023 and 2023-2024 agricultural years, when maximum summer temperatures frequently exceeded 35°C.

The rainfall regime of the Săcele area is among the lowest in the country, and the 2021-2024 agricultural years further emphasized this trend: in 2021-2022, total annual precipitation was below 330 mm, with a pronounced deficit in September, March, April and June, leading to uneven emergence and weak tillering. In 2022-2023, the total rainfall reached approximately 380 mm, yet it was the warmest agricultural year of the entire period, with extended heat stress during stem elongation and grain formation. In 2023-2024, the recorded precipitation dropped below 290 mm, making it the fifth driest year in Romania's modern meteorological history. The absence of rainfall during the critical months of April and May coincided with the spike formation stage, intensifying water stress and reducing both grain weight and the number of fertile tillers.

The average annual wind speed ranges between 4.8 and 5.5 m/s, with prevailing northeasterly winds that further accelerate evapotranspiration and soil moisture loss, especially between April and August. These conditions strongly justify the adoption of minimum tillage systems, which, by reducing soil disturbance and maintaining crop residues on the surface, significantly decrease evaporation, preserve soil moisture, and protect soil structure (Leonte et al., 2024; Dinuta et al., 2025).

From a pedological perspective, the agricultural lands in the Săcele area are dominated by cambic and leached chernozems, developed on loess deposits, with a medium texture (from sandy-loam to loam-clay). The humus content varies between 2.8 and 3.5%, and the soil reaction is slightly alkaline (pH 7.7-8.0). These soils have moderate to good natural fertility but are highly susceptible to moisture loss and structural degradation under conditions of repeated deep tillage and prolonged drought. The water-holding capacity is moderate, estimated at 55-60% of field capacity, which limits the availability of soil water for plants during periods of intense hydric stress.

The experimental activity was conducted over three consecutive agricultural years: 2021-2022, 2022-2023, and 2023-2024, during which the influence of climatic variability on the behavior of several winter wheat varieties cultivated under the minimum tillage system was assessed. The collected data were processed by calculating mean values across the three experimental years to evaluate the overall performance and stability of the tested varieties under variable environmental conditions.

The minimum tillage system applied consisted of performing a reduced number of soil operations, limited to shallow loosening at 10-15 cm depth, partial retention of crop residues on the surface, and seedbed preparation using a light combinator, followed by direct sowing. This method helps conserve soil moisture, reduce wind erosion, and lower energy consumption, in line with the findings reported by Leonte et al. (2024) and Dinuta et al. (2025).

For the purpose of this study, four winter wheat varieties were selected: Avenue, Katarina, Rubisko, and Sorrial, each characterized by a high yield potential and different levels of adaptability to thermal and water stress. The variety Avenue is known for its good drought tolerance and stable performance under variable conditions; Katarina shows rapid autumn development and high winter hardiness; Rubisko stands out for its superior grain quality and high protein content; and Sorrial is

appreciated for its resistance to major foliar diseases and strong tillering capacity.

The wheat crop was established annually in October, during the optimal sowing period for southern Dobrogea, on land previously cultivated with rapeseed, considered one of the best preceding crops for wheat due to its positive effects on soil structure and reduction of disease and pest pressure in cereals (Georgiev et al., 2024). The sowing density ranged between 400 and 450 viable seeds per square meter, with a row spacing of 12.5 cm and a sowing depth of 5 cm, using a seeder compatible with the minimum tillage system.

Fertilization was applied according to crop development stages and climatic conditions in each year. Balanced NPK doses were used, supplemented with foliar fertilizers and biostimulants, which enhanced root development and increased resistance to abiotic stress (Cioineag & Cristea, 2015; Iosub et al., 2022). Specifically, basal fertilization consisted of NPK complex fertilizers (18-46-0) applied at sowing at a rate of 200 kg/ha, followed by nitrogen top-dressing (ammonium nitrate) applied in early spring (BBCH 21-25) at 100 kg N/ha. Foliar fertilizers and biostimulants based on micronutrients and humic substances were applied during stem elongation (BBCH 30–32). Weed control was achieved through selective herbicides applied post-emergence at recommended doses during early growth stages (BBCH 12–16), while disease management was ensured by modern fungicides adapted to warm and dry climatic conditions applied at key phenological stages (BBCH 31–39 and BBCH 51–59), as recommended by recent research (Nita et al., 2024).

Throughout the growing season, the crop was systematically monitored to capture the influence of climatic and technological factors on plant development. Observations focused on plant density at emergence and tillering, average height at maturity, spike formation, and crop uniformity. Before harvest, representative samples were collected to determine the main morpho-productive indicators: number of grains per spike, grain weight per spike, thousand-kernel weight (TKW), test weight, and average yield per hectare. For the assessment of fertile tillers per plant, measurements were conducted using a systematic sampling approach based on 1 m² observation areas (eight adjacent rows over a length of 1 m), with three replicates per variety. Within each sampling unit, plants were randomly selected and the number of fertile tillers per plant was recorded. Observations were performed at key phenological stages: after emergence (first true leaf stage, BBCH 11), before winter dormancy, after winter recovery, and prior to harvest. The collected data were averaged across replicates and subsequently across the three experimental years to reflect the overall performance and stability of the varieties under the studied conditions.

Crop monitoring was carried out using both multispectral UAV imagery and Sentinel-2 satellite data (10 m spatial resolution). For satellite-based monitoring, a total of 12 Sentinel-2 images were used, acquired during the three agricultural years (2021-2024) at key phenological stages, specifically during stem elongation and peak vegetation (BBCH 30–59). UAV-based data were collected through 6 flight campaigns conducted during the same phenological stages, with flights performed in each experimental year to capture crop development under different climatic conditions. The term “different climatic conditions” refers to the inter-annual variability in key environmental factors, including air temperature, precipitation, and soil moisture availability. These variables were characterized based on recorded meteorological data for each agricultural year and were considered when interpreting crop development and vegetation index dynamics, particularly in relation to drought intensity and water stress conditions. The acquisition dates corresponded to periods of maximum vegetative activity, ensuring comparability between years. To ensure transparency and reproducibility, the exact acquisition dates of the Sentinel-2 images used in the analysis are provided in Table 1. The images were selected based on cloud-free conditions and their correspondence to key phenological stages of crop development (BBCH 30–59), allowing consistent inter-annual comparison of vegetation dynamics.

Table 1. Sentinel-2 image acquisition dates and phenological stages (2021-2024)

Year	Platform	Acquisition date	BBCH stage	Phenological description
2022	Sentinel-2A	12-04-2022	BBCH 31	Beginning of stem elongation
2022	Sentinel-2B	05-05-2022	BBCH 37	Flag leaf visible
2022	Sentinel-2A	28-05-2022	BBCH 55	Heading
2022	Sentinel-2B	15-06-2022	BBCH 69	End of flowering
2023	Sentinel-2A	10-04-2023	BBCH 30	Start of stem elongation
2023	Sentinel-2B	02-05-2023	BBCH 39	Flag leaf stage
2023	Sentinel-2A	25-05-2023	BBCH 55	Heading
2023	Sentinel-2B	12-06-2023	BBCH 65	Full flowering
2024	Sentinel-2A	08-04-2024	BBCH 30	Stem elongation
2024	Sentinel-2B	30-04-2024	BBCH 37	Flag leaf
2024	Sentinel-2A	22-05-2024	BBCH 55	Heading
2024	Sentinel-2B	05-06-2024	BBCH 61	Beginning of flowering

Multispectral images acquired from both platforms were processed to derive the Normalized Difference Vegetation Index (NDVI) and other vegetation parameters, including canopy cover, vegetation vigor, and spatial variability of crop development. The combined use of UAV and satellite data allowed for a complementary assessment of crop conditions, integrating the high spatial resolution of UAV imagery with the temporal consistency of Sentinel-2 observations. For each UAV flight campaign, multiple overlapping images were acquired, with the number of images varying depending on the size of the monitored area and flight configuration. The acquired imagery was processed using a standard photogrammetric workflow, including image alignment, dense point cloud generation, and orthomosaic production, resulting in a georeferenced orthomosaic for each campaign.

Flights were performed under controlled acquisition parameters, with relatively constant flight altitude and overlap to ensure data comparability, resulting in high spatial resolution imagery (centimeter-level ground sampling distance, GSD). The main acquisition parameters and flight characteristics are summarized in Table 2.

Table 2. UAV flight campaigns and acquisition parameters (2021-2024)

Campaign	Year	Date	No. images	Flight altitude (m)	GSD (cm/pixel)	Output	Climatic conditions
Flight 1	2022	14-04-2022	280	100	3.2	Orthomosaic	Moderate temperature, low rainfall
Flight 2	2022	30-05-2022	310	100	3.1	Orthomosaic	Warm, increasing water stress
Flight 3	2023	12-04-2023	290	100	3.2	Orthomosaic	Favorable moisture conditions
Flight 4	2023	28-05-2023	320	100	3.0	Orthomosaic	Optimal growth conditions
Flight 5	2024	10-04-2024	275	100	3.3	Orthomosaic	Low soil moisture
Flight 6	2024	25-05-2024	300	100	3.2	Orthomosaic	Severe drought conditions

Harvesting was performed mechanically between June 25 and 30 of each experimental year, when grain moisture dropped below 15%. Samples were processed and analyzed following standard agricultural research methodologies. The data obtained were statistically analyzed using the analysis of variance (ANOVA) to identify significant differences among varieties and years, while Pearson correlation analyses were conducted to determine the relationships between yield components and environmental factors. The statistical processing of results ensured the accuracy and reliability of the interpretations, in accordance with the principles stated by Panaitescu et al. (2014).

The applied methodology was designed to assess the combined effects of the minimum tillage system, combined with appropriate variety selection and optimal crop management, contributes to achieving high and stable yields under the pedoclimatic conditions specific to the Dobrogea region. The data obtained were

comparatively analyzed and correlated with the climatic and pedological parameters of the Săcele area, in order to formulate practical conclusions applicable to modern farming practices, consistent with the principles of sustainable and precision agriculture (Haseeb et al., 2025; Raza et al., 2025b).

The cultivation technology applied in the Săcele area was designed to integrate principles of conservative soil management with elements of precision agriculture, through the use of digital tools for crop monitoring and resource optimization. The minimum tillage system consisted of reducing the intensity of soil operations and maintaining crop residues on the surface, thereby limiting water losses through evaporation and preserving soil structure. This approach is particularly suitable under the restrictive pedoclimatic conditions of Dobrogea, contributing to improved moisture conservation and reduced soil compaction (Leonte et al., 2024; Dinuta et al., 2025).

RESULTS AND DISCUSSIONS

Under the pedoclimatic conditions of the Săcele area, the application of the minimum tillage system was associated with yield values ranging between 4.3 and 5.9 t/ha across the three experimental years. Despite pronounced interannual variability in rainfall, the system supported relatively stable crop development, as reflected by consistent morpho-productive parameters and strong correlations between NDVI and yield. These results indicate that minimum tillage contributed to maintaining wheat performance under drought-prone conditions.

The results further highlight that under increasingly restrictive climatic conditions characterized by rainfall deficits and thermal stress, conservative tillage technologies such as minimum tillage play an important role in ensuring yield stability and agroecosystem sustenability (Kheiralipour et al., 2024; Raza et al., 2025a; Shi et al., 2025).

To further characterize crop development under these conditions, vegetation indices such as canopy cover, vegetation vigor and spatial variability of crop development. Image aquisition was performed at key phenological stages particularly during stem elongation and peak vegetation (BBCH 30-59). These measurements provided essential information regarding crop density, uniformity of emergence, the degree of water stress, and nutrient use efficiency. The NDVI values recorded during the peak vegetation stage were correlated with yield using pooled data across all varieties, establishing a clear positive relationship between higher NDVI values and increased productivity, as also observed by Haseeb et al. (2025) and Joshi et al. (2024).

Complementary to these monitoring activities, a biofertilization program was implemented, based on natural formulations rich in beneficial microorganisms and humic acids. These products were used to stimulate soil microbial activity and enhance nutrient availability, contributing both to agronomic efficiency and to maintaining the ecological balance of the soil system, in line with the findings of Kheiralipour et al. (2024).

Disease and pest management were carried out through integrated plant protection strategies, tailored to the local climatic conditions and phytosanitary status of the crop. During years with high thermal stress and limited rainfall, foliar disease pressure: particularly powdery mildew (*Blumeria graminis f. sp. tritici*) and septoria leaf blotch (*Zymoseptoria tritici*), remained moderate, but preventive treatments were applied using systemic, broad-spectrum fungicides at calibrated doses according to phenological observations. Weed control was gererally low to moderate during the growing season, with dominant dicotyledonous species such as *Galium aparine* and *Stellaria media.* The applied control measures were effective in maintaining a low level of infestation without significant competition effects on crop development.

In the driest years (2021-2022 and 2023-2024), an increased presence of coleopteran pests: especially *Zabrus tenebrioides*, was observed, confirming findings reported by Talmaciu et al. (2024). This trend highlights the influence of drought and high temperatures on pest dynamics, which can intensify crop vulnerability under arid conditions.

The integration of precision agriculture tools, including Global Positioning Systems (GPS) and Geografic Information Systems (GIS), together with UAV-based monitoring,

contributed to a better identification of spatial variability in crop vigor and pest-affected areas. This approach supported more efficient crop management and improved the overall response to biotic and abiotic stress factors, in accordance with the principles of site-specific management (Raza et al., 2025b).

Overall, the technological package implemented under the minimum tillage system contributed to improved crop performance, as reflected by the obtained yield values (4.3-5.9 t/ha) and the strong positive correlations between yield and key indicators such as NDVI (r = 0.97), thousand kernel weight (r = 0.94). And test weight (r = 0.91). Under the restrictive pedoclimatic conditions of Dobrogea, the application of precision technologies and biofertilization supported efficient resource use and enhanced crop stability, as also indicated by the consistent performance of adaptable varieties such as Rubisko and Avenue (Gheorghe & Nicolae, 2023; Kheiralipour et al., 2024; Nita et al., 2024).

The average NDVI values recorded for the four analyzed wheat varieties (Avenue, Katarina, Rubisko, and Sorrial) show a distinct interannual variation across the growing seasons, closely related to the climatic and rainfall patterns of each year (Figure 1). The highest average NDVI values were recorded in the 2022-2023 agricultural year (with approximately 380 mm of annual rainfall and a mean temperature of 12.5°C), when the index ranged between 0.72 and 0.78, indicating a vigorous vegetative growth and high photosynthetic activity.

In contrast, during 2021-2022 and especially 2023–2024, NDVI values decreased significantly (0.58-0.68), which may be associated with prolonged pedological drought and thermal stress affecting green biomass development. The 2023-2024 season, with rainfall below 290 mm, was the most restrictive, leading to a reduction in active leaf area and irregular crop density, as also reflected by the lower NDVI values derived from UAV multispectral imagery (Figure 1).

Among the tested varieties, Rubisko consistently exhibited the highest NDVI values, indicating higher vegetation vigor and suggesting a better adaptability to the given environmental conditions, followed by Avenue and Sorrial. These differences are consistent with previous studies reporting stable performance of modern wheat varieties under conservative soil management systems, supporting the observed varietal differences in this study (Gheorghe & Nicolae, 2023; Dinuta et al., 2025).

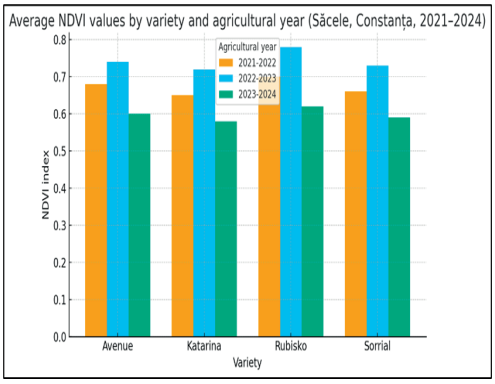


Figure 1. Average NDVI values by wheat variety and agricultural year (Săcele, Constanța, 2021-2024)

The correlation analysis between mean NDVI values and wheat yield across the three experimental years revealed a strong positive relationship (r = 0.97), confirming the reliability of NDVI as an early indicator of crop performance under precision agriculture systems (Figure 2). Higher NDVI values were directly associated with higher yields, reflecting the beneficial effect of a dense and healthy canopy on dry matter accumulation and grain filling.

The 2022-2023 agricultural year, characterized by relatively favorable rainfall distribution and moderate temperatures during grain filling, recorded the highest average yield (6.4 t/ha), corresponding to the maximum NDVI value (0.74). Conversely, the 2023-2024 season, marked by extreme drought and heat stress, showed the lowest NDVI (0.59) and an average yield of 4.1 t/ha, illustrating the strong sensitivity of winter wheat to hydric stress in arid environments. The close NDVI–yield relationship confirms the potential of multispectral imagery and vegetation indices as powerful tools for yield modeling and site-specific resource management. These results are in line with studies by Haseeb et al. (2025) and Raza et al. (2025a), which demonstrated that the

integration of optical sensors and remote sensing algorithms in agricultural monitoring systems allows optimized fertilization and phytosanitary treatments, reducing yield losses under extreme climatic variability.

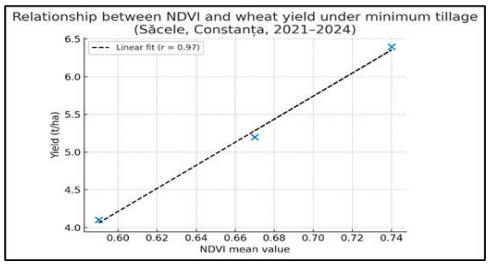


Figure 2. Relationship between average NDVI values and wheat yield across the three experimental years (inter-annual analysis) under the minimum tillage system (r = 0.97)

Under such pedoclimatic constraints, the implementation of the minimum tillage system in the Săcele area represents a well-adapted technological approach. By minimizing soil disturbance and maintaining crop residues on the surface, this system contributes to improved water-use efficiency, reduced fuel consumption, and erosion control, without significant yield penalties. These findings are consistent with results reported in other parts of Dobrogea (Ghiorghe et al., 2024; Nita et al., 2024).

Tillering represents one of the most important phenological stages in the development of wheat, having a decisive role in determining the yield potential by establishing the number of fertile tillers that contribute to the final spike density. This process is strongly influenced by soil moisture and temperature conditions during autumn and early spring, as well as by soil fertility and the cultivation technology applied (Panaitescu et al., 2014; Dinuta et al., 2025).

Under the pedoclimatic conditions of the Săcele area, characterized by low annual rainfall and mild winters, tillering occurred more slowly but uniformly, especially under the minimum tillage system, where crop residues retained higher moisture levels in the upper soil layers. The measurements revealed moderate differences between varieties, with average values ranging between 2.8 and 3.5 fertile tillers per plant, and a general mean of 3.1. The varieties Rubisko and Avenue showed the highest tillering capacity (3.5 and 3.3 fertile tillers per plant, respectively), due to their strong vegetative vigor and well-developed root systems, which allowed for better utilization of soil moisture. The variety Katarina exhibited a moderate tillering capacity (2.8 tillers per plant), typical for short-stature genotypes, while Sorrial recorded an intermediate value (3.0 tillers per plant), demonstrating balanced adaptation to both thermal and hydric stress.

The results confirm that the minimum tillage technology promotes more uniform tillering compared to conventional systems, due to better moisture conservation and reduced thermal fluctuations in the germination layer. Overall, the behavior of the analyzed varieties indicates a good adaptive capacity, with clear genetic differences among genotypes, an important advantage when selecting varieties suited to the pedoclimatic conditions of Dobrogea.

Plant height is a fundamental morphological indicator, reflecting each variety's ability to utilize available water and nutrient resources and to adapt to the pedoclimatic conditions specific to the cultivation area. Plant stature is influenced by both genetic characteristics and cultivation technology, as well as by soil fertility and climatic factors (Axinte et al., 2006; Panaitescu et al., 2014).

The measurements conducted in the agricultural area of Săcele, Constanța County, within the experiment carried out under the minimum tillage system during the 2021-2024 agricultural years, revealed notable differences among the analyzed varieties. The reported values represent multi-year means calculated across the three experimental years. The average plant height ranged between 83 cm and 92 cm, with a general mean of 88 cm for the entire experimental period. Among the four studied varieties, Rubisko exhibited the greatest height (92 cm), followed by Avenue (89 cm), Sorrial (87 cm), and Katarina, which showed the lowest height (83 cm) (Figure 3). These differences reflect both the genetic distinctiveness of each variety and their variable adaptive capacities to the restrictive conditions of the Dobrogea region, where rainfall is limited and thermal stress is frequent. The greater height of Rubisko can be associated with strong vegetative growth and enhanced ability to exploit deep soil moisture, an advantage conferred by its robust root structure and adaptability to semi-arid

conditions (Nita et al., 2024; Georgiev et al., 2024).

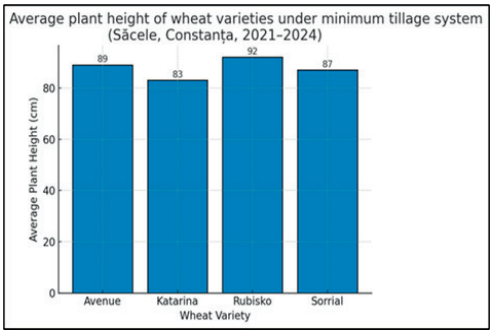


Figure 3. Average plant height of wheat varieties under minimum tillage system (Săcele, Constanța, 2021-2024, mean values across three experimental years)

The Avenue variety, although slightly shorter, displayed constant growth and high morphological stability, which was accompanied by elevated NDVI values recorded in the 2022-2023 season. In contrast, Katarina's shorter stature represents a genetically designed trait, offering increased lodging resistance and metabolic efficiency during dry years, when plants with extensive leaf area are more susceptible to excessive evapotranspiration. Sorrial exhibited intermediate behavior, showing balanced and uniform growth, well adapted to the minimum tillage system, which better preserves soil moisture in the active layer. The general mean height of 88 cm is slightly below the values reported for more humid regions of Romania, such as the Pecica-Arad area where higher plant heights have been observed under more favorable water conditions (Pop et al., 2024) a difference explained by the pedoclimatic characteristics of southern Dobrogea, where water stress limits vegetative growth (Leonte et al., 2024; Dinuta et al., 2025). Nevertheless, the relatively uniform values recorded for key morpho-productive parameters, such as plant height and tillering capacity, across experimental plots demonstrates a good adaptability of modern wheat varieties to local environmental conditions and confirms the efficiency of the minimum tillage system in maintaining balanced plant development. The results indicate that Rubisko performed best in terms of morphological development, followed by Avenue and Sorrial, while Katarina, despite its shorter height, stood out through stability and stress tolerance. The comparative analysis confirms that variety selection, combined with the application of conservative technologies, represents a key factor in ensuring uniform growth and a high productive potential under the pedoclimatic conditions of the Dobrogea region. The grain mass per spike and the number of grains per spike are key morpho-productive indicators of the agronomic value of wheat, being closely correlated with the final yield. Under the restrictive pedoclimatic conditions of the Săcele area: characterized by low annual rainfall (below 330 mm in 2021-2022, approximately 380 mm in 2022-2023, and below 290 mm in 2023-2024), these two traits reflected both the genetic differences among varieties and the influence of annual climatic variability on grain formation and filling processes.

The yield results showed clear differences among the analyzed wheat varieties across the three experimental years (Figure 4). In 2021-2022, the average yield was 5.2 t/ha, with higher values recorded for Rubisko and Avenue, while Katarina showed the lowest performance. In 2022-2023, the most favorable year, the average yield increased to 6.4 t/ha, maintaining the same varietal ranking. In contrast, during the driest year (2023-2024), the average yield decreased to 4.1 t/ha, although Rubisko and Avenue continued to exhibit better adaptability under drought conditions compared to Sorrial and Katarina. These differences were supported by statistical analysis (ANOVA, $p < 0.05$), confirming the significant effect of varietal characteristics and climatic conditions on yield performance.

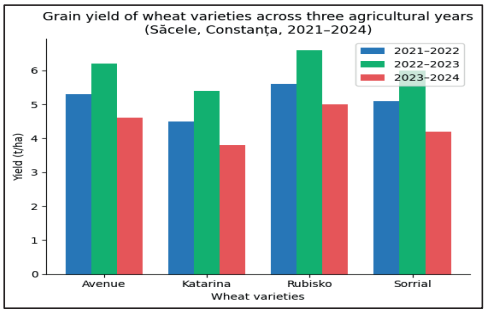


Figure 4. Grain yield of wheat varieties across three agricultural years (Săcele, Constanța, 2021-2024).

On average, Rubisko recorded 48 grains per spike and a grain mass per spike of 2.08 g, ranking first; Avenue registered 47 grains per spike and 2.02 g; Sorrial had 46 grains per spike and 1.98 g; while Katarina, despite its shorter stature and good stress resistance, reached 45 grains per spike and 1.93 g (Figure 5). The results show a positive relationship between the number and the mass of grains per spike across all varieties. Rubisko recorded the highest values (48 grains/spike and 2.08 g), confirming its superior fertility and adaptability under drought-prone conditions. Avenue and Sorrial exhibited stable intermediate performances, while Katarina had the lowest averages, consistent with its shorter and more conservative growth type. The data indicate that vigorous varieties achieved better grain filling under the minimum tillage system due to improved soil moisture conservation, and the observed differences were statistically significant (ANOVA, $p < 0.05$). The hierarchy correlates with both NDVI values and average plant height, suggesting that vegetative vigor and efficient water use under the minimum tillage system contributed to better grain filling and superior spike fertility. The differences among varieties were statistically confirmed through ANOVA, while positive correlations between the number and mass of grains per spike and yield were supported by correlation analyses, in agreement with previous studies reporting similar relationships between spike fertility, components and yield performance, where higher grain number and grain weight per spike were associated with increased productivity (Nita et al., 2024; Pop et al., 2024).

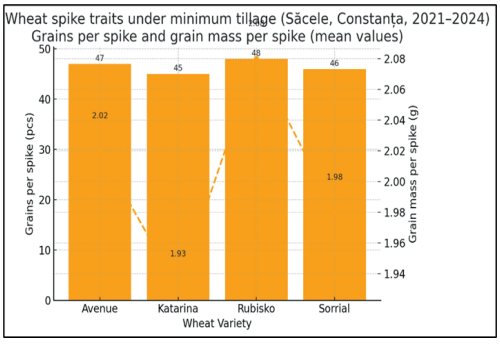


Figure 5. Wheat spike traits under minimum tillage (Săcele, Constanța, 2021–2024): grains per spike and grain mass per spike (mean values)

The thousand kernel weight (TKW) values recorded in this study ranged between 40.8 g and 44.1 g, reflecting differences in grain filling and varietal performance under pedoclimatic conditions of Săcele area. These variations indicate the influence of both genetic characteristics and environmental factors, particularly water avaibility and nutrient use efficiency during the grain filling period (Roman et al., 2013; Stroe & Panaitescu, 2025). Under the restrictive climatic conditions of the Săcele area, where the annual rainfall was below the multiannual average (≈330 mm in 2021-2022, ≈380 mm in 2022-2023, and below 290 mm in 2023-2024), TKW values ranged between 40.8 g and 44.1 g, with a general mean of 42.6 g. Among the tested varieties, Rubisko recorded the highest value (44.1 g), confirming its superior grain-filling capacity and resistance to water stress. Avenue (43.2 g) and Sorrial (42.5 g) showed intermediate values, while Katarina (40.8 g) had the lowest kernel weight, correlated with its shorter stature and more conservative growth rate (Figure 6).

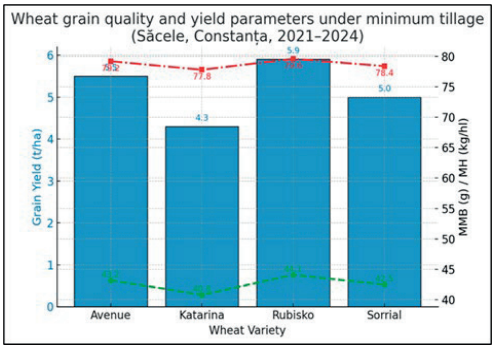


Figure 6. Wheat grain quality and yield parameters under minimum tillage (Săcele, Constanța, 2021-2024)

The test weight (TW), an indicator of grain density and physical quality, ranged between 77.8 and 79.6 kg/hl, with an average of 78.7 kg/hl. The high values recorded for Rubisko (79.6 kg/hl) and Avenue (79.2 kg/hl) indicate a complete grain filling and good physiological condition of the crop, even under drought conditions. Sorrial (78.4 kg/hl) and Katarina (77.8 kg/hl) showed slightly lower quality, but still within the standards for bread wheat.

Regarding grain yield, the average values obtained over the three agricultural years (2021-

2024) ranged between 4.3 and 5.9 t/ha, showing similar trends to NDVI and test weight (TW). The most productive variety was Rubisko with an average of 5.9 t/ha, followed by Avenue (5.5 t/ha), Sorrial (5.0 t/ha), and Katarina (4.3 t/ha).

The results confirm that the interaction between genotype and the minimum tillage technology, under accentuated drought conditions, significantly influences both the quality and productivity of the crop. Varieties with higher vegetative vigor and deeper root systems, such as Rubisko and Avenue, were more efficient in utilizing residual moisture and nutrients, maintaining good yield stability during dry agricultural years. The differences among varieties were statistically significant (ANOVA, $p < 0.05$), and correlation analyses revealed positive relationships between TKW, TW, and average yield, confirming that these indicators can serve as reliable predictors of yield performance in the arid climate of Dobrogea. The results highlight a clear positive relationship between grain yield, thousand kernel weight (TKW), and test weight (TW) across the studied wheat varieties. The variety Rubisko showed superior performance for all parameters, confirming its high adaptability and physiological efficiency under drought-prone conditions. Avenue also maintained stable yield and grain quality, while Sorrial and Katarina achieved slightly lower values, consistent with their more conservative growth patterns. The data demonstrate that varieties combining strong vegetative vigor with efficient resource use achieve both higher yield and better grain quality under the minimum tillage system in semi-arid regions.

The results revealed strong and relationships between morpho-productive parameters and agronomic performance particularly, between average yield, thousand kernel weight (TKW), test weight (TW), and the NDVI index.

The results revealed strong positive correlations between yield and TKW (r = 0.94), as well as between yield and TW (r = 0.91), confirming that well-developed grains and high endosperm density are key determinants of yield performance under drought conditions. Furthermore, the correlation between NDVI and yield (r = 0.97) suggests that NDVI can serve as reliable predictive indicator for estimating yield potential and supporting data-driven crop management decisions. The regression analysis indicated a significant linear relationship ($p < 0.05$) between NDVI and yield ($R^2 = 0.93$), demonstrating that variations in active biomass can explain over 90% of the yield variability under the climatic conditions of the study area. A strong positive linear relationship was observed between NDVI values and average grain yield across the studied wheat varieties ($R^2 = 0.93$). Varieties with higher NDVI, such as Rubisko and Avenue, achieved greater productivity, reflecting their superior vegetative vigor and efficient resource utilization under drought-prone conditions. The regression model indicates a strong relationship between NDVI and yield performance ($R^2 = 0.93$), suggesting the potential of NDVI as an indicator for yield estimation under minimum tillage systems (Figure 7). The NDVI values used in this analysis are higher than those presented in Figure 2, as they represent varietal averages derived from peak vegetation stages, reflecting maximum canopy development. The correlations between yield and other parameters such as thousand kernel weight (TKW) and test weight (TW), are presented based on numerical statistical analysis in the text, without additional graphical representation. While Figure 2 illustrates the NDVI–yield relationship based on inter-annual variability, the following analysis focuses on the varietal-level relationship, highlighting differences in crop performance among the studied wheat varieties.

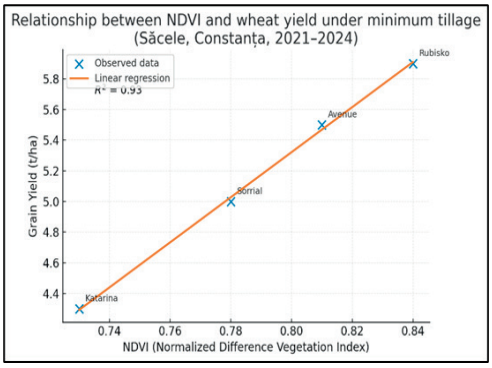


Figure 7. Relationship between average NDVI values and grain yield at the varietal level under minimum tillage (Săcele, Constanța, 2021-2024).

Within the experiment conducted in the Săcele area, the minimum tillage technology was

complemented by the application of precision agriculture tools aimed at optimizing crop management and monitoring plant development. Vegetation monitoring was carried out using both UAV multispectral imagery and Sentinel-2 satellite data, from which NDVI was derived to assess canopy uniformity and crop vigor across different phenological stages. Based on these data, fertilizer rates and phytosanitary treatments were adjusted accordingly, reducing over-application and improving cost efficiency. Variable-rate applications were performed using GPS-guided equipment and spatial data derived from UAV and satellite monitoring, ensuring precise and uniform distribution, thereby enhancing input efficiency and minimizing environmental impact. The integration of these digital tools demonstrated significant benefits in managing abiotic stress and maintaining a balance between productivity and sustainability, confirming the potential of precision agriculture in optimizing wheat cultivation under the arid climatic conditions of Dobrogea.

CONCLUSIONS

The results obtained from the study conducted in the Săcele area, Constanța County, during 2021-2024, highlight the adaptability of the wheat varieties Rubisko and Avenue to the restrictive pedoclimatic conditions of Southern Dobrogea, as reflected by their higher yield performance and NDVI values under low rainfall and frequent thermal stress. The application of the minimum tillage system contributed to soil moisture conservation, structural stability, and reduced energy consumption in field operations.

Among the tested varieties, Rubisko consistently achieved the highest morpho-productive performance, with superior values for grain weight, test weight, and average yield (5.9 t/ha), confirming its enhanced efficiency in resource use and strong drought tolerance. The varieties Avenue and Sorrial demonstrated good yield stability and grain quality, making them suitable for conservative farming systems, while Katarina, though more moderate in growth, showed stable performance and can be recommended for areas facing pronounced water stress.

Statistical analyses revealed strong positive correlations between yield, thousand kernel weight, test weight, and NDVI ($r = 0.91$-0.97), while the linear regression analysis ($R^2 = 0.93$) indicated a strong association between NDVI and yield. These findings highlight the value of integrating precision agriculture tools, such as multispectral imaging and variable-rate input application, to support improved wheat management under drought-prone conditions.

In conclusion, combining minimum tillage practices with digital monitoring and the selection of locally adapted varieties contributes to stable wheat production under the pedoclimatic conditions of southern Dobrogea. It is recommended to expand future research through multi-location and long-term trials, focusing on the cumulative effects on soil fertility and resource efficiency, as well as on the integration of AI-based predictive models to improve climate risk forecasting and adaptive management strategies.

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