ISSN 2313-092X
E-ISSN 2411-9199
UDC: 631.4:631.58(477.63)

Ukrainian Black Sea Region Agrarian Science
Vol. 30, No. 2
DOI: 10.56407/bs.agrarian/2.2026.09

The impact of Mzuri Pro-TIL technology on winter wheat productivity under natural and artificial moisture conditions in southern Ukraine

Vyacheslav Shebanin
Doctor of Technical Sciences, Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0002-0391-396X

Antonina Drobitko
Doctor of Agricultural Sciences, Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0002-6492-4558

Marek Ruzhniak
Doctor of Agricultural Sciences
Mzuri World
89-110, 1 Stawowa Str., Smielin, Poland
https://orcid.org/0009-0007-7762-4232

Iryna Smirnova*
PhD in Agricultural Sciences, Associate Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0002-8976-3818

Tetiana Kachanova
PhD in Agricultural Sciences, Associate Professor
Mykolaiv National Agrarian University
54008, 9 Georgiy Gongadze Str., Mykolaiv, Ukraine
https://orcid.org/0000-0003-0032-3996

Abstract. The article presents the results of studies on the effect of the resource-saving strip tillage technology Mzuri Pro-TIL on the formation of productivity of winter wheat of the Duma Odeska variety under conditions of natural and artificial moisture in the south of Ukraine. The aim of the research was to assess the impact of the Mzuri Pro-TIL technology on the growth, development and productivity of winter wheat under natural and irrigated conditions in southern Ukraine compared with the conventional cultivation technology. A set of generally accepted scientific methods was employed, including analysis and synthesis for theoretical generalisation of the material, as well as laboratory and field methods to obtain reliable empirical data under controlled and natural conditions. The influence of the studied technologies on plant growth and development, stand formation, yield structure components and grain yield of winter wheat was analysed. It was established that the application of the

Article's History:
Received: 17.11.2025 Revised: 24.04.2026 Accepted: 26.05.2026 Published: 30.06.2026

Suggested Citation:
Shebanin, V., Drobitko, A., Ruzhniak, M., Smirnova, I., & Kachanova, T. (2026). The impact of Mzuri Pro-TIL technology on winter wheat productivity under natural and artificial moisture conditions in southern Ukraine *Ukrainian Black Sea Region Agrarian Science*, 30(2), 9-19. doi: 10.56407/bs.agrarian/2.2026.09.

*Corresponding author (smirnova@mnau.edu.ua)

Mzuri Pro-TIL technology creates favourable conditions for the autumn development of winter wheat, promotes increased tillering, higher stand density and greater intensity of linear plant growth during the growing season. Under irrigation, the positive effect of the technology was enhanced, as evidenced by increased plant height, a greater number of productive stems and improved formation of generative organs. The Mzuri Pro-TIL technology ensured higher values of spike length and weight, number of spikelets and grains per spike, grain weight per spike and thousand-grain weight compared with the conventional tillage system. The average grain yield under the Mzuri Pro-TIL technology amounted to 5.70 t/ha under natural moisture conditions and 6.56 t/ha under irrigation, exceeding the conventional technology by 0.83 and 0.68 t/ha, respectively. The obtained results confirm the feasibility of the integrated application of modern strip tillage technology and optimisation of the water regime as an effective approach to increasing the productivity of winter wheat in the south of Ukraine

Keywords: strip tillage; plant height; thousand-grain weight; tillering coefficient; Duma Odeska; irrigation; yield

INTRODUCTION

Winter wheat is still strategically important in the crop rotation in southern Ukraine; however, in recent years there has been a decline in its yield and a deterioration in grain quality, which often fails to meet food standards. The main causes are increased abiotic stresses (moisture deficit, high temperatures, uneven rainfall) combined with biotic factors that negatively affect yield formation. The aridisation of the region's climate makes the development and implementation of adaptive, resource-efficient cultivation technologies particularly relevant, aimed at the efficient use of soil moisture, the preservation of soil fertility and the stabilisation of high-quality grain production.

One way to adapt agriculture to climate change, protect soil from erosion and achieve high yields of winter crops is to adopt new technologies, primarily those aimed at minimising tillage (the use of surface loosening technology (Mini-TIL) and zero tillage (No-TIL), strip tillage systems using Mzuri Pro-TIL technology, and a transition to rain-fed farming. Another approach involves the rational use of water for irrigation and the adoption of innovative irrigation methods (drip and subsurface). Strip tillage using the Strip-TIL system from Mzuri Pro-TIL involves working a narrow 12 cm-wide strip of soil, leaving crop residues on the surface between rows (24 cm, 36.4 cm or 58 cm depending on the setting), which allows moisture and organic matter to remain in the soil, as well as helping to increase the earthworm population, significantly improve soil biota composition, enhance soil structure, and more. The use of Mzuri Pro-TIL sowing units creates an ideal seedbed for achieving synchronised plant emergence, enabling crops to withstand climatic stresses and maximise their genetic potential.

The Mzuri Pro-TIL seed drill operates on the principle of precision strip tillage, combining the cutting of crop residues, loosening of the seedbed and the simultaneous application of fertiliser to a specified depth. Roll-down ensures optimal seed-to-soil contact, which improves germination rates and sowing uniformity. Research by I. Koženiauskas (2021) has shown that such strip tillage has a positive effect on the soil's agrophysical properties, reduces energy consumption during tillage, helps preserve soil structure and minimises the negative impact on the environment. In turn, this improves resource efficiency and crop yield stability, which is particularly important under conditions of limited moisture and intensive farming. Such precise localised application helps preserve soil structure, reduce energy costs for tillage and increase crop productivity.

In recent scientific research, considerable attention has been paid to assessing the effectiveness of resource-saving soil cultivation technologies in the context of increasing climate instability. In particular, the study by V. Shebanin *et al.* (2025) conducted a comprehensive assessment of the economic efficiency of winter wheat cultivation using the Mzuri Pro-TIL technology. The authors found that the implementation of this technology reduces production costs by cutting the number of operational steps, reducing fuel consumption and optimising the use of mineral fertilisers through their localised application to the root zone of the plants. Research has also demonstrated that the Mzuri Pro-TIL technology contributes to increased yield stability of winter wheat, particularly under conditions of insufficient and erratic moisture supply, which is characteristic of southern Ukraine. The authors emphasise that leaving plant residues on the soil surface and minimising disturbance to its structure have a positive effect on the soil's hydration regime, reduce moisture loss through evaporation and improve the efficiency of rainfall utilisation.

According to research by O. Mayorov & M. Tsekhmeystruk (2021), it has been established that the conventional method of wheat cultivation involves soil preparation, sowing, crop management and harvesting.

Soil preparation involves ploughing, cultivation and harrowing to create a uniform seedbed, which provides optimal conditions for seed germination and root system development. Sowing is carried out in accordance with sowing dates and rates, whilst crop management includes fertiliser application, protection against weeds, pests and diseases, and soil moisture control. Harvesting is aimed at minimising grain losses and preserving grain quality. Research by V. Hakhula & Y. Kiruta (2023) have shown that conventional farming also improves aeration, mixes organic matter and distributes moisture evenly, but intensive tillage can compact the lower soil layers, contribute to erosion and reduce fertility, as well as requiring high energy and material costs. Thus, conventional farming ensures stable yields, but is limited in terms of preserving long-term soil fertility and the efficient use of resources.

The importance of state support for the introduction of innovative technologies in agriculture is particularly significant under martial law, when ensuring food security and economic stability is paramount. The Mzuri Pro-TIL technology aligns with these priorities, as it helps to increase yields, promote the efficient use of resources and reduce production costs, even under adverse conditions. Scientific research, notably the work of Z. Ding *et al*. (2020) and M. Habib-Ur-Rahman *et al*. (2022), confirm that resource-saving technologies enable increased wheat productivity, reduced tillage and preservation of soil structure, which positively impacts the fertility and environmental sustainability of agricultural production. At the same time, the issue of the economic efficiency of applying the Mzuri Pro-TIL technology in the Ukrainian agricultural sector requires further study, in particular an assessment of implementation costs and potential yield increases. Taking these aspects into account will enable a well-founded recommendation for the large-scale application of the technology in southern Ukraine to enhance the productivity and economic stability of agricultural production. The aim of the research was to determine the impact of the Mzuri Pro-TIL technology on the growth and development of winter wheat under natural and artificial irrigation conditions in southern Ukraine, compared with conventional technology.

MATERIALS AND METHODS

The study was conducted between 2022 and 2024 at the experimental field of the Educational, Scientific and Research Centre of Mykolaiv National Agrarian University, located in the southern soil and climate zone of Ukraine. The soil of the experimental plot is a southern chernozem of medium humus content, with a humus content in the arable layer of 2.8-3.2%; the soil solution pH is close to neutral. The climate of the zone is characterised by insufficient moisture, high air temperatures in summer and an uneven distribution of precipitation throughout the year. The study utilised the soft winter wheat variety "Duma Odeska", which was entered into the State Register of Plant Varieties Suitable for Distribution in Ukraine in 2017. The variety is characterised by high yield potential, adaptability to the soil and climatic conditions of the Steppe and Forest-Steppe zones of Ukraine, and resistance to major diseases and abiotic stress factors, in particular drought and low temperatures (State Register of Plant Varieties..., 2024). The winter wheat was sown on 10 October at a seeding rate of 2.5 million seeds per hectare.

The experimental design included cultivation variants using the Mzuri PRO-TIL technology: Factor A: technology: 1 – Mzuri PRO-TIL, 2 – conventional; Factor B: irrigation method: 1 – natural, 2 – irrigation. The area of the sown plot was 1.2 ha, and the plot area was 0.5 ha. The experiment was repeated three times, with plots arranged in a sequential design. The agronomic practices for growing the crops under study were standard for the Southern Steppe region of Ukraine, with the exception of the factors under investigation. The Mzuri-ProTil technology involved the use of a specialised seed drill, which in a single pass provided localised soil loosening, application of mineral fertilisers and precise seed sowing. The row spacing under strip tillage technology was 12 cm between rows within a strip and 36.4 cm between adjacent strips. Conventional technology involved a full cycle of primary and pre-sowing soil cultivation using traditional agricultural practices and a standard crop management system.

In the irrigated treatments, a sprinkler irrigation system using front-type sprinkler equipment was employed. Irrigation was carried out in accordance with the biological requirements of the crop during the critical growth and development stages of winter wheat (tillering, stem elongation, heading, and grain filling). Soil moisture was monitored using the thermostatic-gravimetric method by taking soil samples from the arable layer (0-30 cm) prior to irrigation. Moisture content was determined as a percentage of the mass of absolutely dry soil. The criterion for irrigation was a reduction in soil moisture to 70-75% of the minimum moisture capacity (MMC) Irrigation rates were set on a case-by-case basis depending on actual soil moisture, meteorological conditions and the crop's growth stage. Water application was recorded based on the sprinkler's technical specifications and irrigation duration, followed by a calculation of the total irrigation rate for the growing season.

Growth parameters for the autumn growing season of winter wheat were determined during the 2022-2023 period, and for the spring growing season during the 2023-2024 period. Plant height was determined by measuring the distance from the soil surface to the tip of the ear (excluding awns) in 20 representative plants at each plot using a measuring ruler; the average value of the indicator was calculated based on the results. The number of stems was determined by counting the total number of productive stems in a sample of 20 plants in each experimental treatment, followed by conversion to an average per plant. Ear width was measured with a vernier caliper at the central part of the ear. To improve accuracy, three consecutive measurements were taken of each ear with slight rotation around the axis, and the maximum value was recorded; the arithmetic mean for the sample was entered into the tables. The length of the ear was determined from the base to the tip (excluding awns), with the results subsequently averaged.

The bushiness coefficient was defined as the ratio of the total number of developed stems to the number of plants in the sample. To this end, 20 representative plants were selected from each plot, the total number of stems (productive and non-productive) was counted, and the average per plant was calculated by dividing the total number of stems in the sample by the number of plants counted. The number of spikelets per ear was determined by counting their total number on 20 representative ears selected from each experimental treatment; the data obtained were averaged. The number of grains per ear was determined by threshing each of the 20 selected ears individually, followed by manual counting of the grains and calculation of the average value. The grain weight per ear was determined by individually threshing 20 ears selected from each experimental treatment on a representative basis. The grains obtained from each ear were weighed individually on electronic scales to an accuracy of 0.01 g. The average value of the indicator was calculated based on the measurement results. The weight of 1,000 grains was determined in accordance with current methodological guidelines: two samples of 500 grains each were taken from the average grain sample, weighed on electronic scales, after which the obtained value was doubled and the average calculated; the results were reported to an accuracy of 0.1 g (DSTU ISO 520:2015, 2015). Grain yield was determined using the total accounting method by harvesting from the accounting area of each plot, followed by conversion to 1 ha and adjustment to standard grain moisture content (14%). The experimental data obtained during the studies were subjected to mathematical and statistical analysis using the specialised software "Agrostat". To determine the influence of the studied factors and their interaction on the productivity indicators of winter wheat, methods of analysis of variance (ANOVA) were applied. The statistical significance of differences between the mean values of the variants was determined using the significance criterion at a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

The results of the studies reflect the impact of the Mzuri Pro-TIL technology on the yield potential of winter wheat under natural and artificial irrigation conditions in southern Ukraine. The analysis of the data obtained was carried out taking into account the specific soil and climatic conditions of the study area, the hydrothermal regime during the observation years, and the biological characteristics of the Duma Odeska cultivar. The main focus is on assessing the response of winter wheat plants to the application of the resource-saving strip tillage technology, which combines local loosening with the simultaneous application of mineral fertilisers, compared to the traditional tillage system. The research results indicate that the use of the Mzuri Pro-Til technology creates more favourable conditions for plant growth and development during the autumn growing season, which is crucial for the formation of winter wheat yield potential. The retention of plant residues on the soil surface, the improvement of its agrophysical properties and the more efficient use of soil moisture, particularly under conditions of limited moisture, had a positive effect on the initial stages of the crop's organogenesis.

It is the autumn growth of plants and the level of vegetative mass development prior to the cessation of vegetative growth that determine the intensity of tillering, winter hardiness and the subsequent course of growth processes in spring. In this regard, the next stage of research is aimed at assessing the state of growth processes in Duma Odeska winter wheat prior to winter set-in under various tillage technologies and irrigation regimes, which allows us to substantiate the impact of the Mzuri Pro-Til technology on the realisation of the crop's productive potential. At the beginning of the third ten-day period of November, the winter wheat was in the tillering stage, which is critical for the formation of the plant stand and the crop's potential yield (Table 1). Under the Mzuri Pro-TIL technology, the height of winter wheat plants under natural moisture conditions was 21.1 cm, whilst under irrigation conditions it increased to 23.5 cm. A similar trend was observed for the tillering coefficient, which increased from 2.5 to 3.1 units. The number of stems using this technology also increased – from 665.0 to 736.3 stems when switching from natural moisture to irrigation. Under the traditional technology, an increase in all studied indicators was observed under the influence of irrigation: plant height increased from 20.1 to 21.9 cm, the tillering coefficient from 1.8 to 2.2 units, and the number of stems from 688.1 to 841.0. Moreover, the difference between the technologies was statistically significant ($p < 0.05$), indicating the effectiveness of Mzuri Pro-TIL in the formation of productive stems and the preparation of winter wheat for overwintering in the conditions of the Southern Steppe of Ukraine.

Table 1. *Growth status of Duma Odeska winter wheat crops before winter set-in (average for 2022-2023)*

Technology (factor A)	Indicator	Irrigation method (factor B)	
		natural	irrigation
Mzuri Pro-TIL	plant height, cm	21.1 ± 0.61	23.5 ± 0.68
	tillering coefficient, units	2.5 ± 0.07	3.1 ± 0.09
	number of stems, pcs.	665.0 ± 19.2	736.3 ± 21.3
Conventional	plant height, cm	20.1 ± 0.58	21.9 ± 0.63
	tillering coefficient, units	1.8 ± 0.05	2.2 ± 0.06
	number of stems, pcs.	688.1 ± 19.9	841.0 ± 24.3

Source: *compiled by the authors*

Meanwhile, the data in the table shows that, with the Mzuri Pro-TIL technology, the initial plant density was slightly lower than with the traditional method. However, due to the higher tillering coefficient and better plant survival during the autumn growing season, this technology ensured the formation of a more uniform and potentially productive stand. This indicates increased crop adaptability and more efficient utilisation of the plants' biological potential. Analysis of the obtained indicators suggests that the plants were in good physiological condition: the leaf area was sufficient for effective photosynthesis, and the root system was adequate to ensure water and nutrient uptake. The high level of plant development in irrigated plots confirms the effectiveness of supplementary irrigation in increasing potential yield.

During the first ten days of May, agrometeorological conditions for winter wheat growth were satisfactory. At the same time, due to a lack of rainfall, there was a rapid depletion of available moisture from both the topsoil and subsoil layers. On irrigated plots, a single sprinkler irrigation was carried out at a rate of 300 m^3/ha. More developed plants consumed moisture and nutrients more intensively, outpacing the growth of weakened plants and increasing their suppression by shading them from the sun (Table 2).

Table 2. *Growth dynamics of winter wheat crops depending on irrigation method and cultivation system (average for 2023-2024), cm*

Technology (factor A)	Growth and development stages	Irrigation method (factor B)	
		natural	irrigation
Mzuri Pro-TIL	stem elongation	40.9 ± 1.18	46.9 ± 1.35
	ear emergence	76.2 ± 2.20	80.5 ± 2.33
	milk ripeness	90.4 ± 2.61	96.8 ± 2.80
Conventional	stem elongation	31.3 ± 0.90	37.8 ± 1.09
	ear emergence	67.3 ± 1.94	75.9 ± 2.19
	milk ripeness	86.9 ± 2.51	92.6 ± 2.67

Source: *compiled by the authors*

Studies have shown that the Mzuri Pro-TIL cultivation technology delivers consistently higher shoot growth in winter wheat compared to the traditional system at all key stages of development – from stem elongation to milk ripeness. Supplementary irrigation significantly increases plant height, particularly in the early (stem elongation) and late (milk ripeness) stages, highlighting the importance of optimal water supply for the formation of a productive canopy and the realisation of yield potential. The difference between the technologies was statistically significant ($p < 0.05$), and irrigation increased all growth parameters compared to natural moisture, demonstrating the effectiveness of Mzuri Pro-TIL in enhancing growth intensity and the formation of productive winter wheat stems. The greatest increase in plant height was observed during the milk ripeness stage, highlighting the critical importance of water management and modern technologies for maximising the crop's genetic potential. The data demonstrate the effectiveness of an integrated approach, where the application of advanced technology is combined with optimised irrigation, ensuring better development of morphological traits and the plants' potential yield. Many factors influence the yield of winter wheat, including irrigation methods and cultivation techniques. Depending on these, different plant densities are formed (Table 3).

Table 3. *Plant density of winter wheat at the stage of full grain maturity, depending on irrigation method and farming practices (average for 2023-2024), plants/m²*

Technology (factor A)	Indicator	Irrigation method (factor B)	
		natural	irrigation
Conventional	total number of stems	565 ± 16.3	625 ± 18.1
	including productive stems	501 ± 14.5	562 ± 16.2
Mzuri Pro-TIL	total number of stems	648 ± 18.7	714 ± 20.6
	including productive stems	583 ± 16.8	643 ± 18.6

Source: *compiled by the authors*

In plots with natural moisture levels, the highest plant density was observed during the stem elongation and heading stages, when temperatures rose. Research findings indicate that the plant density of winter wheat was influenced by both cultivation practices and weather conditions. Thus, the highest plant density of 714 plants per 1 m^2 was achieved by the Duma Odeska crop under irrigation and Mzuri Pro-TIL. Studies determined that a greater number of productive stems were formed in irrigated plots using the technologies under investigation. Overall, winter wheat crops produced a higher number of productive stems using the Mzuri Pro-TIL technology, both under natural moisture conditions and on irrigated plots, which was 82 plants/m^2 and 81 plants/m^2 respectively more than with the traditional technology. The plant density of winter wheat at full maturity was higher with the Mzuri Pro-TIL technology compared to the traditional system, with irrigation increasing plant density, and the difference between the technologies was statistically significant ($p < 0.05$), confirming the effectiveness of Mzuri Pro-TIL in the formation of productive winter wheat stems.

The higher number of productive stems at the stage of full grain maturity achieved using the Mzuri Pro-TIL technology is due to a combination of agrobiological and technological factors. First and foremost, this system involves minimal disturbance of the soil profile and the retention of plant residues on the surface, which promotes better moisture accumulation and retention, stabilisation of soil temperature, and activation of microbiological processes. Under such conditions, a more developed root system forms, the efficiency of nutrient utilisation increases, and moisture losses are reduced, which has a positive effect on autumn tillering and the preservation of shoots during the winter period. As a result, a larger proportion of the stems formed in autumn do not die off but survive until the ripening phase and realise their productive potential. Thus, the Mzuri Pro-TIL technology ensures a denser stand and a greater number of productive stems compared to the traditional system, regardless of the irrigation method. Irrigation further increases plant density, boosting both the total number of stems and the number of productive ones, which confirms the importance of water management in achieving high crop yields. Overall, combining modern cultivation technology with optimal moisture management promotes more efficient utilisation of plant potential and the formation of a more productive stand, which is a key factor in increasing winter wheat yield. The second key indicator of winter wheat productivity is the grain weight per ear. In the studies conducted, this ranged from 1.03 g using conventional technology under natural moisture conditions to 1.56 g using the Mzuri Pro-TIL technology on irrigated plots, demonstrating a significant increase in productivity when modern technology and optimal water supply are applied (Table 4).

Table 4. *Performance indicators for winter wheat at the stage of full grain maturity, depending on irrigation method and cultivation technology (average for 2023-2024)*

Indicator	Mzuri Pro-TIL technology Irrigation method		Conventional technology Irrigation method	
	natural	irrigation	natural	irrigation
Ear length, cm	10.3 ± 0.30	11.5 ± 0.33	9.5 ± 0.27	10.1 ± 0.29
Ear width, cm	1.4 ± 0.04	1.5 ± 0.04	1.1 ± 0.03	1.1 ± 0.03
Ear weight, g	3.43 ± 0.10	3.53 ± 0.10	2.25 ± 0.07	3.15 ± 0.09
Number of spikelets per ear, pcs.	20 ± 0.58	22 ± 0.64	17 ± 0.49	19 ± 0.55
Number of grains per ear, pcs.	54 ± 1.56	60 ± 1.73	48 ± 1.39	56 ± 1.62
Grain weight per ear, g	1.49 ± 0.04	1.56 ± 0.05	1.03 ± 0.03	1.08 ± 0.03
Weight of 1,000 grains, g	42.5 ± 1.23	45.8 ± 1.32	34.0 ± 0.98	35.4 ± 1.02

Source: *compiled by the authors*

The highest values for ear length (11.5 cm) and width (1.5 cm) were recorded in winter wheat grown using the Mzuri Pro-TIL method with irrigation. Under natural moisture conditions, these figures are slightly lower (10.3 cm and 1.4 cm respectively). The conventional technology yields smaller ear parameters: a length of 9.5-10.1 cm and a width of 1.1 cm, regardless of moisture conditions. This indicates the positive impact of modern technology and supplementary water supply on ear formation. The Mzuri Pro-TIL technology produces a higher ear weight: 3.43 g under natural moisture conditions and 3.53 g with irrigation, whereas with the conventional technology, ear weight ranges from 2.25 to 3.15 g. The number of spikelets per ear and grains per ear was also higher with Mzuri Pro-TIL, particularly on irrigated plots: 22 spikelets and 60 grains per ear compared to 19 spikelets and 56 grains per ear with conventional technology under irrigation. Irrigation improved all indicators of winter wheat productivity compared to natural moisture supply, and the difference between the technologies was statistically significant ($p < 0.05$), which substantiates the effectiveness of Mzuri Pro-TIL in the formation of productive ears and the increase in winter wheat grain yield under the conditions of the Southern Steppe of Ukraine. All these factors also influenced the grain yield of winter wheat. The research results indicate that the use of Pro-TIL technology ensures higher yields in all years of the study and under both moisture regimes, particularly when combined with irrigation (Fig. 1). This points to more efficient use of soil moisture and more favourable conditions for yield formation compared to conventional tillage technology.

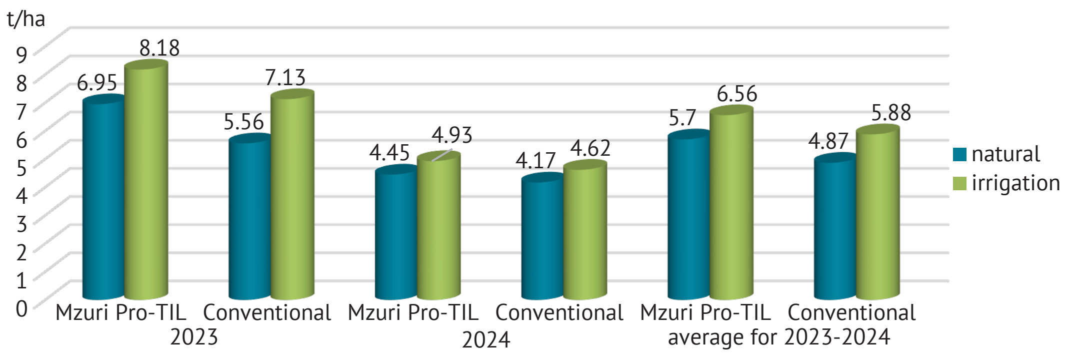

Figure 1. *Winter wheat grain yield by cultivation method and irrigation method (average for 2023-2024), tonnes per hectare*

Source: *compiled by the authors*

In 2023, under natural irrigation conditions, the yield using the Mzuri Pro-TIL technology was 6.95 t/ha, which exceeded the corresponding figure for the conventional technology (5.56 t/ha) by 1.39 t/ha. Under irrigation conditions, an increase in yield was observed in both variants; however, the highest value was recorded specifically for the Mzuri Pro-TIL technology – 8.18 t/ha, whereas for the conventional technology it was 7.13 t/ha. This indicates the higher efficiency of the energy-saving technology when combined with irrigation. In 2024, the overall yield level was lower compared to 2023. Under natural moisture conditions, the yield using the Mzuri Pro-TIL technology was 4.45 t/ha, whereas with the conventional method it was 4.17 t/ha. Under irrigation conditions, yields increased to 4.93 t/ha (Mzuri Pro-TIL) and 4.62 t/ha (conventional technology). The advantage of the Mzuri Pro-TIL technology remained, although the difference between the variants was less pronounced than in 2023.

The average data over two years confirm the consistent advantages of the Mzuri Pro-TIL technology. Under natural irrigation conditions, the average yield was 5.70 t/ha, which is 0.83 t/ha higher than that achieved with conventional technology (4.87 t/ha). Under irrigation conditions, the average yield using the Mzuri Pro-TIL technology reached 6.56 t/ha, whereas with the conventional method it was 5.88 t/ha. According to the results of the analysis of variance, it was determined that the NIR05 for factor A was 0.25 t/ha, and for factor B – 0.37 t/ha. Joint studies demonstrate that strip tillage technologies contribute to a comprehensive increase in winter wheat productivity. Thus, D. Xu. (2022) found that Strip-TIL improves plant growth, nitrogen use efficiency and yield in a rice-wheat rotation, which is consistent with improved stem development in trials using the Mzuri Pro-TIL technology. Similarly, Q. Wang *et al.* (2024) demonstrated that the combination of Strip-TIL and periodic deep loosening promotes better nitrogen uptake and higher winter wheat productivity. Furthermore, D. Hobson *et al.* (2022) noted the positive impact of strip tillage on root system development, photosynthetic parameters and grain filling, which influences 1,000-grain weight and overall yield. Finally, a meta-analysis indicates a general trend towards higher crop yields with Strip-TIL compared to conventional technology.

At the same time, as noted by V. Havrysh *et al.* (2020), the introduction of energy-saving technologies in agriculture is a priority area for improving production efficiency. The Mzuri Pro-TIL technology fully meets these requirements, as it reduces the number of passes made by machinery across the field, ensuring the rational use of energy resources and cutting production costs. Unlike traditional precision farming systems, which focus on high-precision seed and fertiliser application, Mzuri Pro-TIL offers a comprehensive approach: simultaneous strip tillage, fertiliser application and seedbed preparation. Such integration of operations not only reduces energy and material costs but also increases crop yields, making the technology economically viable and promising for large-scale implementation in resource-efficient farming.

Recent scientific research indicates that the adoption of resource-saving soil cultivation techniques, particularly strip tillage, plays a key role in enhancing the adaptability of agricultural production to arid conditions. According to G. Taye *et al.* (2024), minimising mechanical disturbance to the soil helps reduce moisture loss through evaporation and curb erosion processes, which is particularly important for regions with unstable moisture conditions. Improving soil structure enhances its water permeability and water-holding capacity, creating more favourable conditions for plant growth and yield formation.

Research findings confirm the conclusions of M. Lozinskiy *et al.* (2021) that grain weight per ear is a key factor in winter wheat productivity, and show that the Mzuri Pro-TIL technology increases grain weight and 1,000-grain weight through strip tillage, localised fertiliser application and the retention of plant residues. These findings are consistent with those of M. Rozewicz *et al.* (2024), who noted improvements in soil porosity and aeration, reduced compaction and stimulation of the root system, which increases the efficiency of water and nutrient use.

The use of resource-saving techniques in winter wheat cultivation, in particular strip tillage systems, helps to increase productivity and make more efficient use of soil moisture, as well as ensuring that the genetic potential of the varieties is realised, which is particularly important when growing wheat following sunflowers in the Southern Steppe region of Ukraine (Gamayunova *et al.*, 2022). Similar results were obtained in studies by M. Korkhova *et al.* (2023), where it was established that optimising stubble tillage improves the agrophysical properties of the soil and contributes to increased winter wheat productivity. The results obtained are consistent with the data presented and confirm the effectiveness of the Mzuri Pro-TIL strip tillage technology, which ensures better moisture retention and higher crop yields in the conditions of the Southern Steppe of Ukraine. Water availability and nutrient supply are key factors in determining winter wheat yield, as they influence the intensity of growth processes and the realisation of the varieties' productive potential. Research shows that increasing moisture levels and optimising mineral nutrition contribute to a significant increase in the yield of winter wheat varieties (Gamayunova *et al.*, 2022; Korkhova & Panfilova, 2024). In the conditions of the Southern Steppe of Ukraine, where crop productivity may decline due to climatic constraints or external factors such as armed conflict, the application of adaptive technologies becomes extremely relevant (Nasibov *et al.*, 2024). Combining the Mzuri Pro-TIL strip-till technology with natural or artificial irrigation ensures more efficient use of soil moisture and nutrients, creating favourable conditions for increasing winter wheat productivity in the region.

The results of the studies are consistent with the findings of Q. Chen *et al.* (2021), who demonstrated that minimised and strip tillage improve soil physico-chemical properties, conserve moisture and promote root system development, thereby increasing the yield of field crops. Furthermore, K. Song *et al.* (2019) demonstrated that combining minimum tillage with the return of crop residues improves soil structure, stabilises organic carbon and increases crop yields. In current studies, the Mzuri Pro-TIL technology, which combines strip tillage, localised fertiliser application and the retention of plant residues, ensured optimal soil water and nutrient conditions, increased the density of productive stems and grain weight, leading to higher winter wheat yields. This confirms that the integration of modern tillage technologies, taking into account varietal characteristics and water regime, effectively realises the crop's productive potential.

CONCLUSIONS

Studies conducted in Ukraine between 2022 and 2024 have shown that the Mzuri Pro-TIL technology creates favourable conditions for the growth of the Duma Odeska winter wheat, ensuring consistently higher linear plant growth, greater tillering and stem density compared to the conventional tillage system. This demonstrates the effectiveness of the resource-saving strip tillage technology, which combines localised soil loosening with the application of mineral fertilisers, in shaping the morphological characteristics of the crop. Irrigation significantly increases plant productivity, particularly during critical development stages – stem elongation and milk ripeness. Additional water supply promotes the formation of a more productive canopy, active shoot growth and the effective utilisation of the variety's genetic potential. The use of Mzuri Pro-TIL technology in combination with optimal water supply stimulates the formation of larger and more productive ears, increasing their length, width, weight, number of spikelets and grains per ear, as well as the weight of a single grain and the weight of 1,000 grains. These factors directly contribute to an increase in the potential yield of winter wheat.

According to the results of two years of observations, the average winter wheat yield using the Mzuri Pro-TIL technology was 5.70 t/ha under natural irrigation and 6.56 t/ha under artificial irrigation, exceeding the figures for conventional technology by 0.83 and 0.68 t/ha respectively. This confirms the effectiveness of an integrated approach, where modern tillage technology is combined with optimised water management. The use of Mzuri Pro-TIL technology ensures a higher number of productive stems, a denser stem stand and better grain-filling of the ears, which are key factors in increasing the yield and stability of winter wheat production in the southern region of Ukraine. The research results demonstrate the importance of the combined effect of agronomic practices: combining a modern tillage system with optimal water supply allows the variety's potential to be realised to the fullest and enables the effective use of available natural resources. In the future, a detailed study is planned to investigate the impact of the Mzuri Pro-TIL technology and various irrigation regimes on grain quality indicators, including morphological, physiological and technological characteristics. This will enable a more comprehensive assessment of the effectiveness of an integrated approach to winter wheat cultivation and optimise the farming system to improve grain yield and quality in the southern region of Ukraine.

ACKNOWLEDGEMENTS

None.

FUNDING

None.

CONFLICT OF INTEREST

None.

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Вплив технології Mzuri Pro-TIL на продуктивність пшениці озимої за умов природного та штучного зволоження півдня України

В'ячеслав Шебанін
Доктор технічних наук, професор
Миколаївський національний аграрний університет
54008, вул. Георгія Ґонґадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0002-0391-396X

Антоніна Дробітько
Доктор сільськогосподарських наук, професор
Миколаївський національний аграрний університет
54008, вул. Георгія Ґонґадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0002-6492-4558

Марек Ружняк
Доктор сільськогосподарських наук
Mzuri World
89-110, вул. Ставова, 1, м. Смєлін, Польща
https://orcid.org/0009-0007-7762-4232

Ірина Смірнова
Кандидат сільськогосподарських наук, доцент
Миколаївський національний аграрний університет
54008, вул. Георгія Ґонґадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0002-8976-3818

Тетяна Качанова
Кандидат сільськогосподарських наук, доцент
Миколаївський національний аграрний університет
54008, вул. Георгія Ґонґадзе, 9, м. Миколаїв, Україна
https://orcid.org/0000-0003-0032-3996

Анотація. У статті наведено результати досліджень впливу ресурсоощадної технології смугового обробітку ґрунту Mzuri Pro-TIL на формування продуктивності пшениці озимої сорту Дума одеська за умов природного та штучного зволоження в умовах півдня України. Метою досліджень було оцінити вплив технології Mzuri Pro-TIL на ріст, розвиток і продуктивність пшениці озимої за умов природного та штучного зволоження півдня України порівняно з класичною технологією вирощування. Для проведення дослідження було використано комплекс загальноприйнятих наукових методів, зокрема аналіз і синтез для теоретичного узагальнення матеріалу, а також лабораторні й польові методи для отримання достовірних емпіричних даних у контрольованих і природних умовах. У процесі проведення досліджень застосовували загальноприйняті наукові методи, зокрема аналіз і синтез, а також комплекс лабораторних і польових методів. Проаналізовано вплив досліджуваних технологій на ріст і розвиток рослин, формування стеблостою, елементи структури врожаю та урожайність зерна пшениці озимої. Встановлено, що застосування технології Mzuri Pro-TIL створює сприятливі умови для осіннього розвитку пшениці озимої, сприяє підвищенню кущистості, щільності стеблостою та інтенсивності лінійного росту рослин упродовж вегетації. За умов зрошення позитивний ефект технології посилювався, що проявлялося у збільшенні висоти рослин, кількості продуктивних стебел та кращому формуванні генеративних органів. Технологія Mzuri Pro-TIL забезпечила вищі показники довжини й маси колоса, кількості колосків і зерен у колосі, маси зерна з колоса та маси 1 000 зерен порівняно з традиційною системою обробітку ґрунту. Середня урожайність зерна за технології Mzuri Pro-TIL становила 5,70 т/га за природного зволоження та 6,56 т/га за зрошення, що відповідно на 0,83 і 0,68 т/га перевищувало показники класичної технології. Отримані результати підтверджують доцільність інтегрованого застосування сучасної смугової технології обробітку ґрунту та оптимізації водного режиму як ефективного напряму підвищення продуктивності пшениці озимої в умовах півдня України

Ключові слова: смуговий обробіток ґрунту; висота рослин; маса тисячі зерен; коефіцієнт кущистості; Дума одеська; зрошення; урожайність